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Vol. XXI January to December, 1916

JOURNAL

OF THE

WESTERN SOCIETY

OF

ENGINEERS

PAPERS, DISCUSSIONS, ABSTRACTS, PROCEEDINGS

CHICAGO
PUBLISHED BY THE SOCIETY
1735 Monadnock Block

SUBSCRIPTION PRICE $3.00 PER VOLUME
OF TEN NUMBERS

CONTENTS BY NUMBERS

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B. E. Grant

PRESIDENT

OF THE

WESTERN SOCIETY OF ENGINEERS

1916

Journal of the

Western Society of Engineers

VOL. XXI. JANUARY, 1916 No. 1

PROPOSED CODE OF ETHICS—FOR COMMENT

In the early part of 1915, President Jackson, by authority of the Board of Direction, appointed a committee to consider the question of the adoption by the Western Society of Engineers of a Code of Ethics, the committee so appointed consisting of Messrs. H. B. Herr, Chairman, John W. Alvord, C. R. Dart, P. Junkersfeld and C. F. Loweth.

This committee has submitted a report to the Board of Direction, which, by order of the Board, is printed herein for the purpose of giving the membership of the Society an opportunity to express their views upon it before any formal action is taken. Communications on the subject should be addressed to the Secretary.

November 26, 1915.

To the Board of Direction, Western Society of Engineers:

Gentlemen: The Committee appointed by the President of the Society to "decide whether it will be advisable for the Society to formulate a code of ethics, and if so, to report to the Board of Direction an effective code," begs to submit the following report, and the accompanying code.

REPORT.

Preliminary to any serious study of the subject a copy was obtained of the codes adopted by each of the following Institutes, Societies, and Associations, viz: The American Institute of Electrical Engineers, American Institute of Consulting Engineers, American Society of Mechanical Engineers, American Society of Civil Engineers, Institution of Civil Engineers, London, American Medical Association, American Institute of Architects, and Chicago Bar Association. Each member of the Committee was furnished with a copy of each of these codes.

After ample time for the members to study the codes, a meeting of the Committee was held, at which it was decided, that, in the opinion of the Committee, a code of ethics of the Society is desirable, and the Chairman was requested to compile an abstract, which should embody the points covered by the codes of the above named organizations.

All of these codes are in the form of rules or regulations, each

adaptable to the special professional work represented by the organizations.

In compiling the abstract care was exercised to avoid repetition of similar provisions occurring in the different codes; nevertheless the compilation assumed quite lengthy proportions. A copy of this compilation was furnished each member of the committee.

At a subsequent meeting it was decided that, in the opinion of the Committee, the detailed application of the general ethical principles and ideas as to the relations and conduct of the engineer cannot be effectively incorporated in a set of fixed rules universally applicable. The engineering profession includes many classes and degrees of responsibility, many types of service and a great variety of contractual relationships, which will tend to require modification of any code except one in which only the most general principles of ethics are expressed.

It was also the opinion of the Committee that the best guide to correct detailed professional relations would be a keen appreciation of the general professional status, and a conscientious attempt to be guided in each specific case by the spirit of the ideas set forth in a general concise statement of engineering ethics. Where a doubt arises, helpful advice might be obtained from those qualified to suggest and counsel; and to this end it may be that a standing Society Committee on professional ethics, carefully selected, will be helpful, but such a committee should have advisory and suggestive powers only.

The Committee is of the opinion that Society discipline though necessary in extreme cases, is to be deplored and avoided where possible. The loss of respect of one's profession is usually sufficient punishment for the wilfully guilty.

In the light of these conclusions the Committee has formulated with care and thought a brief and original statement of the basic principles underlying all professional ethics which it believes preferable and sufficient for the needs of the Society and of its members.

This proposed code is herewith submitted, and is recommended for adoption by the Society.

Respectfully submitted,

HIERO B. HERR, Chairman.
JOHN W. ALVORD.
C. R. DART.
P. JUNKERSFELD.
C. F. LOWETH.

A PROPOSED CODE OF ETHICS FOR THE WESTERN SOCIETY OF ENGINEERS

The following code of ethics is intended to cover only the general duties and obligations of the engineer, and is not to be regarded as an attempt to enter into specific directions.

I. A profession is a vocation in life requiring specialized intellectual attainment, which can be usefully devoted to the services of others.

II. The opportunity to serve human society with specialized skill is not confined to the professions, but professional service is peculiar in that it is the product of mental inquiry and analysis upon problems whch cannot be properly solved by purely mechancal skill or training.

III. Competent professional service therefore; whether for the community, the corporation or the individual, requires a certain liberty of thought and action with some freedom from undue direction which is not so noticeable in other callings. This larger requirement, as a trust, carries with it the responsibility of producing the most effective results consistent with all the limiting circumstances.

IV. It follows that a capable professional man should be necessarily and peculiarly the repository of confidence and trust on the part of those whom he well serves, and such necessary confidence and trust should in turn inspire in him as an obligation, the highest sentiments of honor and good faith.

V. The first and highest aim of a professional man should be to render the most effective and efficient service consistent with the opportunities afforded him. Questions of his remuneration cannot properly take precedence of the quality of his service, but must be of secondary importance. It is, however, a secondary duty to see that his services are properly understood, appreciated and sufficiently rewarded by adequate compensation, not only in justice to himself and his family, but as a mark of respect to his profession.

RELATIONS OF PROFESSIONAL MEN TO EACH OTHER.

VI. The adjustment of proper relation between professional men, particularly among those in the same profession, is a very important factor in the public respect and confidence accorded their calling, as well as the usefulness and efficiency of their individual service.

Success in both of these directions is largely determined by the completeness with which each member realizes the fraternal idea; and as a result,

(1) Makes appropriation from the joint inheritance of common professional knowledge,

(2) Receives especial aid tendered by his professional brethren,

(3) And as well, gives to the profession in return unselfish and cordial allegience in all matters.

VII. The engineer is always deeply indebted to his profession in some or all of the following ways:

(a) For the use of the great body of common knowledge of the art freely and laboriously placed on record for his benefit by the pioneers who have gone before him.

(b) By the gratuitous labor of his cotemporaries in promptly offering him in print the result of their experience in both practice and theory,

(c) By the personal help and suggestion he receives (when in good standing) from his cotemporaries in difficult situations of urgency.

(d) For the colleges and libraries which have been created for his instruction, use and benefit by the State and by private liberality.

(e) For the technical societies that afford him opportunity to interchange ideas, and print for the common benefit, opinions, experience and studies in the engineering and useful arts.

(f) For the advantageous position in which he finds himself as a member of a trusted calling, due to the honorable lives and upright characters of those who have preceded him or who lead at the present time,

(g) For the spirit of fraternity and cooperation, which he may enjoy from the members of his profession when he has shown himself, in spirit as well as in the letter, worthy of their professional confidence.

(h) For the further opportunity to enjoy that peculiar esteem and consideration from the laymen of his time which is generously accorded to those who have found respect and merit within the profession itself.

VIII. The recipient of all these opportunities can show his appreciation for those privileges in some degree by the following return:

(a) He can lead an honorable and upright life,

(b) He can regard the profession as a fraternity and act on this theory.

(c) He can lose no opportunity to improve his professional information to the end of bettering his service to his employer or his client,

(d) He can uphold the dignity of his profession by cheerfully giving credit to his cotemporaries for their good work and avoiding all envy or petty jealousy,

(e) He can do his share in supporting societies created for professional benefit and contributing when possible to their store of useful knowledge,

(f) When needfully confronted with the necessity of honorable competition with professional brethren, it should be entered into with the utmost courtesy and consideration for all concerned, and to say the least, without public exhibition of greed, self-laudation, jealousy or ill humor. Some degree of honorable and courteous competition among professional men

is often inevitable, particularly for salaried positions, and at times in all except the higher class of consulting work. This being so, the courtesies and ethics of competition should be studied and cultivated with especial care to the end that the fraternal feeling in the profession does not suffer. Competition in professional work where it enters in at all, should always be on the basis of efficiency in service offered, and never knowingly, in price concessions,

(g) The engineer should always assure himself, as far as possible, that the professional services he renders is in value reasonably in excess of the salary received or fee charged. Where he is in position to fix his own fee, the utmost conscientiousness about charges, is to be observed,

(h) He can be a "gentlemen" always and everywhere. He can follow the "Golden Rule."

THE ENGINEERING PROFESSION.

Engineering is a useful art. Its purpose is to constantly promote a higher civilization for mankind by discovering and creating improvements that are in harmony with natural laws.

The engineer, while at times a scientific discoverer, is more commonly a student and interpreter of science. His chief function is to reduce scientific discovery to practical, useful and economic forms for the safety, comfort and convenience of mankind.

Pure science concerns itself with the discovery of the laws of nature. The engineer ordinarily adapts the discovered laws of nature to the use of man.

While engineering in its elementary operations utilizes mechanical and mathematical methods of expression, which at times gives such work an undue appearance of exactness, these aids properly understood, are, nevertheless, entirely tools subordinate to the chief function of the engineering mind which is essentially judicial and reasoning in character.

The engineer properly analyzing his problem, secures and arrays the facts and develops the evidence affecting the result in each case, tests them in the light of reason and natural law, and judicially determines from the record before him, the proper economic procedure. In all his work to some extent, and in his highest responsibility to a very large extent, he is the final judge who is versed in the science of applying economic truth and natural law, so as to conserve mankind.

Engineering, therefore, being a vocation in life requiring specialized intellectual attainment in the domain of judicial, economic and scientific inquiry and practice, is a profession, and is subject to all the opportunities and restrictions heretofore recited and commonly found to be needful to professional life.

IX. The engineering profession has public duties. In a sense the engineer is in part a public servant. Engineering education is

fostered by public and privately endowed institutions, it is aided by the state and national government by special investigations and publications. This is because the state and the public are keenly alive to the public character of the engineering profession's responsibilities. The life, safety, health, comfort and convenienc of the public is dependent upon the work of the engineer.

In return then, the engineer has public responsibilities to meet and public duties to perform. These are chiefly as follows:

(a) In all engineering problems the public safety ranks first and is above all other considerations,

(b) In the development of the art of engineering, it is incumbent upon the engineer to educate the public up to a right perception and appreciation of engineering problems,

(c) The engineer should always stand ready to voice publicly, safety and security and sound economics in the public administration of engineering,

(d) Service to the public, directly or indirectly is the appropriate and natural opportunity of the engineer, and that it is even less well paid than private service is, perhaps, in part due to the fact that the engineering profession is indebted to the public primarily. Public service, is therefore, a peculiarly honorable service and should be especially respected.

(e) General engineering advice may in certain emergencies, and with reason and caution be appropriately tendered to the public without charge, but not to the prejudice of careful investigations where necessary or to the discouragement of inquiry requiring ample funds, or to the cheapening or discrediting of the public problem in hand.

RECAPITULATION.

X. To recapitulate, the ethical standards of the engineering profession should be those of a fraternity. The engineer should recognize that he is endowed by the profession and the state with specialized knowledge for peculiar, judicial and responsible public service involving the life, safety, comfort and convenience of his own and coming generations, and that in response to these he should so conduct himself as to be appreciative of his indebtedness to his profession for his opportunity, and make return by every effort by a life of special usefulness devoid of unseemly greed, and filled, if possible, with a multitude of those small courtesies, the practice of which encourages the spirit of forbearance and is helpfully conducive to the fine art of living well together.

DESIGN OF A RAILWAY PONTOON BRIDGE

BY H. J. HANSEN, M.W.S.E.

Presented Nov. 8th, 1915.

The Prairie du Chien Division of the C. M. & St. P. Ry. Co. crosses the Mississippi River between Prairie du Chien, Wis., and North McGregor, Ia. About a mile and a half north of the railway crossing the river is divided into two navigable channels, by an interjacent island, as shown in Fig. 1. The total length of each of the structures bridging these channels is about 2,000 ft. The total distance between the North McGregor shore and the Prairie du Chien shore is about 6,000 feet.

The earliest history of the bridges carrying the railroad track across these channels is not known to the writer, but records show that as early as 1857 the C. M. & St. P. Ry. Co. contemplated bridging these two channels, and several designers submitted plans and bids for combination iron and timber structures. However, due to the long draw opening required by the Government on account of logging, none of these plans were carried out, and the then prevailing system of ferrying the railway cars across the river on scows was continued until Mr. John Lawler, at that time freight agent at Prairie du Chien, conceived the idea of the present style of pontoon. In 1874 the first bridge of this type was constructed at this point. It consisted of ordinary pile trestle except the navigable portion of each channel, which was spanned by pontoon draws. The *Engineering News* of June 30, 1883, gives an extract of a paper on this bridge read by Mr. Lawler before an engineering convention at St. Paul.

The present bridge across the east channel consists of a 209 ft. 4 in. pontoon flanked by a girder span on the east end and a truss span on the west end, the remaining portion of the track across this channel being carried on pile trestle. The pontoon was renewed in 1914, at which time the U. S. Government allowed a reduction in the clear opening required, from 350 feet to 160 feet. In addition to the main draw opening, the space under the flanking spans provided a passage for small boats on account of which the pontoon would otherwise have to be opened.

The present bridge across the west channel built in 1900 is composed of a 405-foot pontoon flanked at each end by a 100-foot Howe truss span, the remainder of the structure being pile trestle. This pontoon, a cross-section and part longitudinal elevation of which is shown in Figs. 2 and 3, consists of a scow 405 feet long, 41 feet wide at deck level, 36 feet wide at the bottom and 6 feet deep. Three longitudinal bulkheads consisting of 8 by 16 and 8 by 12 timbers bolted together extend the entire length of the pontoon, the shear between these timbers being transmitted by 2-inch diameter tree nails. The top and bottom joists are 6-inch by 10-inch timber

and the sheathing 3-inch by 10-inch planks. The floor system consists of shallow floor beams supporting two lines of timber stringers. The pontoon is approached from each end on a 30-foot girder span, hinged at the end, resting on the pontoon so as to adjust itself to slight variations between the elevation of base of rail on the pontoon and the approach trestle. When the pontoon is opened, the abutment end of the hinge girders are supported on blocking piled up from the deck of the pontoon and so adjusted that the girders will slide off and onto the abutment bearings.

The floor beams are supported at each end on blocking piled from the deck between vertical guides. These blocks are about 8 inches thick and the elevation of the track is adjusted by varying the number of blocks in accordance with the water level; hydraulic jacks of about 15 tons capacity being employed in raising or lowering the floor beams to adjust the track to the proper level and one floor beam only being moved at a time. The maximum change of track level in one movement is one block or about eight inches.

A separate scow is provided for carrying the swinging machinery. This scow, which is 60 feet long, 30 feet wide and 6 feet deep, also provides storage for about 40 tons of coal. The pull is transmitted from this scow to the pontoon by means of two struts or links, pin-connected to both the scow and the pontoon to allow a certain amount of relative motion. One of these links connects the boats in a transverse direction and the second in a longitudinal direction.

The pontoon is swung by means of a chain having its ends fastened to piles in the river bottom at suitable points and passing over the pontoon and machinery scow with a turn-around and ribbed drum which is driven by a 70-horsepower steam engine. Figure 9 shows the general arrangement of this pulling chain.

To line up the rails of the draw and the approach, the hinge end is provided with a "V" shaped catch placed centrally between the rails on the hinge span directly below the base of rail. This catch engages a socket on the approach as shown in Fig. 4. The rails are lap-spliced and held in place by means of castings marked "R2" in the figure. The rails at the lock end also are lap-spliced, but not clamped as at the hinge end. For a distance of 15 to 18 feet the rails on the approach are not spiked to the ties and at the free end they are connected with a spacing rod and drawn toward the projecting ends of the rails of the pontoon by a weight attached to the rails by a chain passing over a pulley located at one side of the track as shown in Fig. 4a. This weight is about 300 lbs. The rails on the pontoon are bolted to the floor beams so they will not creep either way. At the free end the pontoon is locked into its closed position by a "T" shaped latch connected to the deck of the pontoon. The latch is passed between two vertical timbers or guides with the "T" in a vertical position and turned to a horizontal position behind the guides.

This bridge is swung open about 1,000 times during a season which is equal to about 4.5 openings daily, the greatest number of swings in one week being about 60. During the open season four men are required to operate the bridge, while during the closed season only three men are employed. An average of 11 tons of soft coal is consumed per month in operating the bridge and for heating purposes.

These pontoon bridges have given good service with the exception that during high water with heavy wind storms excessive rolling of the pontoon is experienced, sometimes delaying trains for a considerable length of time and occasionally making it necessary to detour passengers via the La Crosse Division. Their term of service has also been rather short, it being necessary to renew them about every fifteen years. This, to a great extent, is due to the excessive deflection under live load which opens up the joints in the sheathing and works out the caulking strips and caulking thereby causing excessive leakage and deterioration. The deflections of this bridge after being in service for five years are shown in Fig. 5 (a, b, c and d), for various loadings. These deflections are from actual measurements in the field and show clearly the great lack of stiffness.

On account of this heavy deflection and also on account of the heavier loading required, the new pontoons are stiffened by four longitudinal trusses which eliminate this excessive deflection. The actual measured deflection of the new Prairie du Chien pontoon shown in Fig. 5e hardly exceeds ½ inch to ¾ inch for any position of the load, and there can be no doubt that the trussing of these bridges will greatly increase their term of service and reduce the cost of maintaining them.

The bending stresses in these pontoons, however, are reduced very materially on account of their flexibility. This is clearly shown in Fig. 6 (a and b). A 97-ton engine is placed so that its center of gravity coincides with the center of the bridge, assuming the deflection of the structure to be normal, the buoyancy force due to this load is uniformly distributed and represented by the rectangle, a, b, c, d in Fig. 6a. The maximum moment is found at the center and is 8,346,000 foot-pounds.

Fig. 6b shows the deflection curve from Fig. 5a due to the same loading as in Fig. 6a. By multiplying the area, bounded by the deflection curve and the straight line passing through the ends of the pontoon by the width of the pontoon, it was found that the weight of this volume of water is equal to the live load, 194,000 pounds, and that the ends of the pontoon suffered no displacement.

The volume of water displaced in Fig. 6b, of course, is equal to the volume of water displaced in Fig. 6a, but in Fig. 6a the average lever-arm of the buoyancy forces is one-fourth the length of the bridge, or 101 feet, while in Fig. 6b the average lever-arm of the buoyancy forces is only about 39 feet. The actual moment was found to be 2,463,000 foot-pounds as against 8,346,000, which

shows a reduction in bending stresses of approximately 70 per cent due to flexibility.

The reduction in bending stresses due to flexibility will not be as great as this for all positions of the live load, but a material reduction takes place in all cases. For the condition of loading shown in Fig. 7 (a and b) the reduction in moment due to flexibility is 50 per cent.

The new pontoon now being constructed for the west channel to replace the present 405-foot structure is 276 feet 4 inches long. 55 feet wide at deck, 44 feet wide at the bottom and 7 feet 2 inches deep at the center. The clear waterway required is 225 feet, which is a reduction of 130 feet from previous requirements.

This pontoon is of the same general type as the new east channel pontoon and is designed to carry Cooper's E-50 loading modified to include only one locomotive. The aim in this design has been to provide adequate stiffness, to prevent excessive rocking due to wind and waves and to provide machinery for operating the floor and end lifts.

Fig. 8 shows a general plan of this bridge and Fig. 9 the general arrangement of the pulling chain. The structural details are shown in Fig. 10. Part longitudinal elevation, Fig. 11; cross section at L3-U3, Fig. 12; showing cross sections at all panel points except L1 and L3, and Fig. 13, showing a typical cross section between panel points.

The four longitudinal trusses are proportioned to resist the bending and shear forces in that direction, the inside trusses carrying about two-thirds of the live load and the outside trusses the remaining one-third, the transverse shear between the two trusses being transmitted by the vertical transverse bracing at each panel point.

The web members of the trusses consist of vertical posts and diagonal adjustable rods. The vertical struts are composed of four 8 by 8 or in some of the panels four 8 by 10 timbers spaced 1 foot 4 inches apart in a longitudinal direction so as to serve the double purpose of guiding the floor beams and at the same time act as compression members. The chords are composed of 8 by 16 timbers packed and spliced with the railway company's standard Howe truss packing washers and splice clamps, both top and bottom chords being treated alike in this respect on account of the reversal of stress. The stress between the diagonal rods and the chords is transmitted through cast iron bearing blocks having lugs notched into the chords to carry the horizontal component. The stress between the vertical posts and the chords is transmitted through oak sills and caps doweled to both the chords and the posts. These oak blocks were chosen on account of their high bearing value, it being found that in most cases the bearing value of Douglas fir perpendicular to the grain, was inadequate to meet requirements.

The transverse bracing is designed to resist the forces produced in this direction by latching the pontoon at top and bottom

to prevent rolling. Web members in both the vertical and horizontal bracing are composed of diagonal timber struts for compression members and upset steel rods for tension members, connected to the trusses with cast iron angle blocks. The horizontal component of the stress is transmitted to the scow through the angle block "a," the strut "b" and castings "c," having lugs notched into the cross girder "d" and being held in places by bolts through this timber (Fig. 12). To insure a bearing between the vertical post and casting "c" the latter is accurately located and bolted in place before the tension rods in the vertical bracing are tightened. When the nuts are screwed up on these rods, the bottom diagonal struts will force the vertical posts against the castings "c" thus completing the truss system and connecting up with the transverse bracing below the deck.

The joists are 4 by 12 except at the panel points where 8 by 18 timbers are used in the transverse bracing and the middle joists in each panel which are 8 by 12 to receive the butt joints of the sheathing. A smaller depth of joists would be sufficient both for stiffness and strength, but the 12-inch depth is necessary in order to provide clearance for the cast iron bearing blocks and for turning the nuts on the diagonal rods. The sheathing is four inches thick and, except for special shapes, is composed of 4 by 10 inch planking. The scow is caulked on all sides and the sheathing is beveled for caulking as shown in Fig. 13. This view also shows the methods of rabbeting and beveling the end joists for caulking. After the joints have been caulked with oakum, caulking strips are nailed on the top of the oakum to prevent it from working out. All the timber in the pontoon is creosoted except the sheathing, the oak blocks and the machinery supports. The sheathing is not creosoted as previous experience shows that the creosoting process, which has a tendency to soften the wood, makes it impossible to obtain a perfect caulking seam. It was, therefore, decided to paint the sheathing with carbolineum after the pontoon is completed instead of creosoting it.

On the upstream side the scow is protected against the scouring of ice by ¼-inch steel plates bolted and nailed to the sheathing as shown in the cross-sections.

The floor system shown in Fig. 15 consists of shallow steel floor beams and timber stringers connecting up with a 50-foot hinge span at the panel point L3 at each end of the pontoon.

The floor beams are supported on blocking piled between the vertical posts of the inside trusses. This blocking rests on the oak bearing blocks "e," Fig. 15a, which transfer the load to the short struts "f" supported on the oak bearing blocks "g" of the inside trusses.

The track is kept lined up horizontally by timber blocks bolted to the floor beams and guided by the vertical posts. Vertically the track is regulated by varying the number of supporting blocks under the floor beams.

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The stringers consist of two lines of three 10 by 18 timbers bolted together. They are supported between the floor beams on shelf angles and lined up horizontally by lugs bolted to the shelf angles. The stringers are not bolted to the floor beams and their ends are cut on a bevel to allow a certain amount of relative movement of the floor beams in a vertical direction. This precaution is necessary in order to adjust the track by jacks temporarily in case the floor lift machinery should get out of order.

The 50-foot hinge spans are of the ordinary through type plate girder spans with shallow floor, and serve to connect the approach track with the track on the pontoon draw. The pontoon track is elevated about one foot above the approach tracks and the hinge spans are on a grade of about two feet in one hundred when the bridge is unloaded. When a train approaches the pontoon, a gradual displacement takes place until the hinge spans are approximately level when the bridge is fully loaded.

The abutment ends of the hinge spans are provided with rocker shoes, pin connected to the girders, and swinging with the girders when the bridge is opened. The pontoon ends of these hinge spans are supported on and riveted to cross girders at the panel points L3. The ends of these cross girders are provided with pin connected shoes and supported on blocking confined between the vertical posts at L3, similar to the blocking system for the intermediate floor beams. Enough space is left between the cross girders and the posts to allow for a certain amount of rotation about the shoe pins due to live load displacement. The abutment ends of the hinge spans are lifted off of their supports and the spans are carried entirely on the pontoon when the bridge is opened.

The variation of the water level in the Mississippi River is quite considerable, the difference between the extreme high and extreme low water being approximately 22 feet. This extreme difference, however, does not occur very often, and our records show that it has not occurred since 1880, the ordinary yearly variation being only 12 to 16 feet and the maximum daily variation three feet. Fig. 14 shows graphically the weekly variation of the water stage of the Mississippi River at the bridge site during 1912. Provision is made for regulating the track over a range of 16-foot rise and fall of the river. When the water rises to a higher stage than from 16 feet to 17 feet above the zero mark, the approaches have to be raised.

On account of the heavier loading for which this bridge is designed, the floor system is too heavy to be conveniently or economically handled with jacks and, therefore, electrically operated machinery is provided for adjusting the track. The arrangement of this floor lift machinery is shown in Figs. 15 and 16. The track is raised or lowered relative to the pontoon deck by suspending the floor beams from thirty-four ⅝-inch steel cables winding on thirty-four cast iron drums. These drums are mounted on two longitudinal drum shafts, one on each side of the pontoon, and each

of these shafts is driven by a separate back-geared motor through a train of reduction gears. The entire floor system is held in any required temporary position by two brakes operated by a lever in the operator's house.

The hoisting cables are connected to adjustable U-bolts at the under side of the top cords and they are doubled by leading them through loose sheaves running between brackets connected to the top flanges at each end of the floor beam. The cables are then led over loose sheaves on the top of the top cord to the drums.

The load suspended at each cable is 5,000 pounds and by doubling the cables as just described, the direct stress in each part is reduced to 2,500 pounds. The loads at the panel points L3 are considerably more than at the intermediate floor beams and are counterweighted in order to reduce the loads carried by the hoisting cables at these four points to about 3,000 pounds.

Details of cable connections are shown in Fig. 16a.

The two drum shafts are located one on each side of the pontoon between the outer and inner trusses. Each shaft is 198 feet 6 inches long and extends from the panel point L3 at one end to the corresponding panel point L3 at the other end. The shafts are built up of short sections, one panel in length, connected by flange couplings and decreasing in size from 5½ inches in diameter at the center to 3½ inches in diameter at the ends. They are supported on two babbitted bearings at each panel point, the bearings being located at each end of the cable drum which is keyed to the shaft at these points. The cable drums are 14 inches in diameter and 15 inches long, and grooved to receive the cable. Each drum is of sufficient length to receive a maximum length of cable to be wound up when the floor is in its highest position without doubling the layers of cable on the drum.

Each of the drum shafts are operated by one eleven-horsepower direct current back-geared electric motor. These motors transmit motion to the drum shafts through three pairs of reduction gears and are connected electrically to insure simultaneous action on both sides. The gears operating the drum shafts are located at the center of the shafts in order to reduce the twisting moment. The friction brakes are located on the gear shaft next to the motor shafts in each train of gears. They are connected by the equalizing lever to insure an equal amount of braking power at each shaft and are applied by releasing the counterweights on the brake lever arms. Both brakes are operated simultaneously by the lever in the operator's house.

The arrangement of the machinery for lifting the abutment ends of the hinge spans off the abutment supports when the bridge is to be opened is shown in Figs. 15 and 17. It consists of two steel cables, from which the girders are suspended, winding on a cast iron drum driven by an electric motor through a worm and two sets of spur gears.

The hinge span is suspended from the two steel cables, one on each side of the span, by loose sheaves connected to the outside of the girders near the abutment ends. These cables then are led over loose sheaves on the top of the top cords to a cast iron drum located on the deck. This drum is driven with an electric motor through a train of reduction gears.

The hoisting cables are connected to an adjustable "U" bolt in the ends of the top cords extended beyond the trusses for this purpose. The cables are then passed under the loose sheave and led over the loose sheaves on the top of the top cord to the cast iron drum. Both cables are wound on one double drum located on one side of the track, and the cable from the opposite side is lead to the drum by passing it across below the pontoon deck.

Each hinge span is lifted by separate 10-horsepower electric motors located at each end of the pontoon and operated by separate controllers. The motors impart motion to the cable drum through a worm and a train of three pairs of spur gears. The worm not only serves as a speed reducer, but also holds the load in any position where the power is cut off.

The electric power for operating the floor lift and end lift machinery is furnished by a 25 K. W. generator placed on the pontoon and receiving its supply of steam from the boiler that furnishes steam for swinging the bridge.

The arrangement of the swinging machinery is shown in Fig. 15. It consists of the 70-horsepower steam engine from the old bridge, which is operated as previously described, except that the machinery is located on the pontoon instead of on a separate scow. The pontoon is rotated about a hinge pile composed of heavy wrought iron pipe fitted around a wooden pile. The hinge pile is braced to the hinge pier by movable steel straps. The time required to open or close the pontoon 90 degrees is about five minutes, including the time required to lift the girder ends off the abutments.

To keep the rails of the draw and approaches in line, the track at the hinge end is provided with a "V" shaped catch and at the free end with counterbalance weights as shown in Fig. 4a and previously described for the old pontoon; in addition the pontoon is held in position by latches at the deck level and in the plane of the top cords as shown in Section AA, Fig. 15. At the hinge end the latches are adjusted by wedges so that when the pontoon is closed, they slide in position between the vertical guides. At the free end the "T" shaped button fasteners must be turned by hand in order to lock or unlock the bridge. The top latches are used only in rough weather to prevent rocking and transverse rolling of the bridge. Spring buffers are provided at the free end to relieve the shocks from rocking and by closing of the bridge. The bridge is also guided in a longitudinal direction and the details of latches and buffers are shown in Fig. 17a.

The stresses in a pontoon affecting the structure as a whole are produced by unbalanced weight and buoyancy forces. These

stresses are transmitted to and carried in the main longitudinal and transverse trusses. In addition to these stresses the various members may be subject to local stresses caused by concentrated loads on the structure. The local stresses are obtained by the ordinary methods employed for stationary structures and there is nothing new in the theory leading to the main stresses as outlined in the following:

A body resting in still water displaces a volume of water equal to its own weight and its center of gravity lies in the same vertical line as the center of gravity of the water it displaces. This is the condition for equilibrium of any floating body.

When the body is of uniform density and shape, it will experience no stresses, save the compression due to its own weight and the water pressure on its sides. If, however, a concentrated load is placed on the body, then the weight and buoyancy forces no longer balance at every point and shearing and bending stresses are set up which must be resisted by the body.

The buoyancy force per foot of length of a vessel is equal to the volume of water displaced, between two transverse vertical planes, distant one foot apart, multiplied by the weight of water. If, on a base line representing the length of the vessel, we plat this buoyancy force per foot of length below the base line and the weight per foot of length of the structure to the same scale above the base line, we will have a graphical representation of the forces acting on the structure in a vertical direction. The area between the upper curve and the base line is equal to the area between the lower curve and the base line and the centers of gravity of the two areas lie on the same vertical straight line. By adding the ordinates of the two curves and platting the differences, we obtain a new curve called the load curve, having ordinates proportional to the forces producing stress in the structure.

As an illustration, the buoyancy and weight curves for a rectangular scow loaded at the center are shown in Fig. 18b. The condition of loading and the displacement is shown in Fig. 18a. The load, moment and shear curve are shown in Fig. 18c. The condition of loading is as follows:

Dimensions of scow, 40 feet by 10 feet by 5 feet.

Weight of scow uniformly distributed, 20,000 pounds.

Uniform load of 4,500 pounds per linear foot for 15 feet at center. The total load then is 80,000 pounds.

The buoyancy per foot of length is $\frac{80{,}000}{40} = 2{,}000$ pounds.

Weight of scow per lineal foot of length $= \frac{20{,}000}{40} = 500$ pounds.

Weight per foot of center loaded portion $= 4{,}500$ pounds.

In case of rough weather and uneven water surface, the stresses will generally be increased as when a vessel is carried on the crest of a wave, Fig. 19, or astride two consecutive waves as in Fig. 20. The construction of the load curve is essentially the same as for the simple case where the vessel is resting in still water. The weight curve remains unaltered but the buoyancy curve, of course, changes and with it the load curve. It is seen that while the forces acting upon a vessel resting in still water can be accurately determined, the conditions when the water surface is uneven is somewhat different; it being necessary in this case to base our calculations on assumptions covering the most severe conditions.

Our information relative to formation of waves in the Mississippi River at the bridge site is rather meager, but the information obtained would indicate that the maximum wave height reached during high water would hardly exceed one to two feet, and during low water the waves will be correspondingly smaller. A generally adopted theory is that the height of ocean waves are proportional to the square root of their distance from the windward shore. (See Gaillard Wave Action.) At the bridge site the fetch is very small in an east and west direction; besides, any waves that might form in this direction would be broken by the approach trestle and protection work. This, to a certain extent, is also the case in a north and south direction, and in view of this condition the stresses in the longitudinal trusses were computed on the assumption that the pontoon rests in still water when it is closed. For the open position of the pontoon, the wave length is assumed equal to the length of the pontoon and the wave height equal to two feet. This is an entirely arbitrary assumption, based on our experience with these bridges, as ordinarily the height of ocean waves is one-tenth to one-twentieth of the wave length.

The dead load of the pontoon consists of the weight of the scow and trusses assumed to be uniformly distributed, the floor uniformly distributed between panel points L3 and L3, the reaction of the approach girder spans at panel points L3 assumed distributed over four feet, and the machinery, coal and boiler distributed over a length of three panels at each end of the pontoon. The buoyancy and weight curves for dead load pontoon resting in still water are shown in Fig. 21a, and the load curve, moment and shear diagrams are shown in Fig. 23b. The corresponding dead load diagrams for the pontoon resting on a wave crest are shown in Fig. 22 (a and b) and for the pontoon supported astride two consecutive waves in Fig. 23 (a and b). The live load stresses are best obtained by laying out the influence line for the point under investigation.

The equation of the influence line for both moment and shear for a rectangular scow can be reduced to the general form $M = PX + q$, in which M and X are the variables and in which the equation therefore represents a straight line which can be platted by giving two special values to X.

The influence lines to a certain extent depend upon the shape of the scow, and as the pontoon sides are inclined at an angle of 45 degrees, the influence lines for this structure will not exactly coincide with the influence lines derived for a scow of rectangular cross section, and the derivation of the influence line equation becomes much more complicated, due to the fact that for an eccentric load the water plane intersecting the pontoon is no longer a rectangle but a trapezoidal figure that varies with the position of the load, thus introducing a third variable into the equation, which is then no longer an equation of a straight line. The deviation from a straight line, however, is not very great, it being mainly due to the difference between the moment of inertia of a trapezoid and a rectangle, determined by the intersection of the water surface with the pontoon. This difference may be reduced to a negligible quantity by choosing a suitable width of the pontoon and treating it as a scow of rectangular cross section. For the pontoon in question it was found that by considering it as a rectangular cross section of width "b" as shown in Fg. 24 the total error due to this arbitrary assumption would in no case exceed one-tenth of one per cent. In developing the equations of the influence lines it is assumed that the center of gravity of the dead loads coincides with the center of the pontoon.

Fig 25 shows the distribution of dead load over the pontoon and the various positions of the live load having different effect in producing moment and shear are shown in Fig. 25 (a, b and c). The notation is as follows:

$P =$ concentrated live load.
$P_1 =$ concentrated load at panel points.
$W =$ total dead load on bridge.
$W_1 =$ total dead load to left of c.
$R = P + W =$ total dead and live load.
$L =$ length of pontoon.
$b =$ assumed width.
$A = bL =$ area of the assumed bottom of the pontoon.
$h =$ distance from left end to point under investigation.
$x =$ distance right or left from center of pontoon to P.
$x_1 =$ distance to c from center of gravity of all dead load forces to the left of c.

$$e = \frac{PX}{R} = \text{eccentricity.}$$

$$I = \frac{bL^3}{12} = \text{moment of inertia.}$$

$c =$ any point under investigation.
$d_1 =$ draft at left end.
$d_2 =$ draft at right end.

When "R" falls inside the middle third and assuming the weight of water at 62.5 pounds per cubic foot, we have

$$d_1 = \left(\frac{Re\frac{L}{2}}{I} + \frac{R}{A}\right)\frac{1}{62.5} \qquad (A)$$

$$d_2 = \left(-\frac{Re\frac{L}{2}}{I} + \frac{R}{A}\right)\frac{1}{62.5} \qquad (B)$$

The moment at "c" when "P" is to the left of "c" (Fig. 21a)

$$Mc = \frac{62.5\,h^2\,b}{2}\left[d_1-(d_1-d_2)\frac{h}{L}\right] + \frac{2x62.5h^3b}{3x2xL}(d_1-d_2)$$

$$-P\left[x-\left(\frac{L}{2}-h\right)\right]-W_1X_1$$

Substituting the values of d_1 and d_2 from equations A and B and reducing, we obtain:

$$Mc = \left(\frac{3h^2}{L^2}-\frac{2h^3}{L^3}-P\right)X + \frac{h^2}{2L}\left(P+W\right) + \frac{PL}{2} - Ph - W_1X_1$$

This may be written

$$Mc = \left(\frac{3h^2}{L^2}-\frac{2h^3}{L^3}-P\right)X + \frac{PL}{2} - Ph + \frac{h^2W}{2L} - W_1X_1$$

The term $\frac{h^2W}{2L}$ is the moment of the buoyancy forces to the left of the point c about c, for the pontoon resting in still water. The term. W_1X_1 is the moment of the dead load to the left of the point "e" about "c." The expression:

$$\frac{h^2W}{2L} - W_1X_1$$

therefore expresses the resulting dead load moment at the point under investigation and should be considered separately. Omitting the terms representing the dead load moment and giving P the special value 1, we have for the equation of the moment influence line for the assumed position of P,

$$Mc = \left(\frac{3h^2}{L^2}-\frac{2h^3}{L^3}-1\right)X + \frac{L}{2} - h + \frac{h^2}{2L} \qquad (C)$$

When P is to the right of c and to the left of the center of the bridge (Fig. 25b) the equation for moment at c is:

$$Mc = \left(\frac{3h^2}{L^2}-\frac{2h^3}{L^3}\right)X + \frac{h^2}{2L} \qquad (D)$$

When P is on the right half of the span (Fig. 25c)

$$Mc=\left(\frac{2h^3}{L^3}-\frac{3h^2}{L^2}\right)X+\frac{h^2}{2L} \tag{E}$$

The shear at c when P is to the left of c is (Fig. 25a)

$$S=62.5bh\left(d_1-\frac{d_1-d_2}{L}\right)-P-W_1$$

as before by substituting the values of d_1 and d_2 from "A" and "B," reducing, eliminating the dead load shear and giving the special value 1 to P, we obtain the equation of the live load shear influence line at c:

$$S=\left(\frac{6h}{L^2}-\frac{6h^2}{L^3}\right)X+\frac{h}{L}-1 \tag{F}$$

When P is to the right of c and to the left of the center of the bridge the equation reads:

$$S=\left(\frac{6h}{L^2}-\frac{6h^3}{L^3}\right)X+\frac{h}{L} \tag{G}$$

When P is on the right half of the bridge we obtain in a similar manner:

$$S=\left(\frac{6h^2}{L^3}-\frac{6h}{L^2}\right)X+\frac{h}{L} \tag{H}$$

The moment and shear influence lines for the panel point L6 is shown in Fig. 26a and 26b. Between panel points L3 — L3, the results are obtained by multiplying the wheel loads by the ordinates directly. Beyond these points the loads cannot be considered as acting directly on the pontoon and the effect is found by multiplying the girder reaction at L3 by the ordinate directly below. The reaction at L3 of course may be scaled off directly by laying off the influence line for the reaction at L3 as shown in the figures.

The forces producing stress in a transverse direction consist of the unbalanced dead and live load concentrations. The buoyancy and weight curves in a transverse direction for the pontoon resting in still water are shown in Fig. 28.

In case of rough weather with uneven water surface, the transverse stresses are greater on account of wave action and this effect is further increased by guiding the pontoon in a vertical plane as previously mentioned. In this case the difference in water level at the opposite sides of the pontoon is assumed one foot and we then have the condition shown in Fig. 29. The weight of the volume of water displaced is still equal to the weight of the structure with its superimposed loads, but the centers of gravity of the two bodies no longer lie on the same vertical. This condition causes a moment which is resisted by the reactions on the vertical guides. For the assumptions made this reaction is about 75,000 pounds. This stress is carried mostly in the vertical end frames, as owing to the comparative flexibility of the top horizontal lateral truss, only

a small amount is carried to the adjoining vertical frames. Owing to the peculiarity of this structure, impact stresses were eliminated except for the floor beams and hinge spans where 20 per cent of the live load were arbitrarily added to cover impact stresses. For proportioning the various members of this bridge the following unit stresses were used:

Tension in steel rods and bolts	16,000 lbs. per sq. in.
Tension in timber	1,500 " " " "
Bending in timber—extreme fiber stress	1,500 " " " "

Compression in timber 1,500 $\left(1-\frac{L}{60D}\right)$ per sq. in.

Where L = length and D = least depth in inches.

Bearing perpendicular to the grain	400 lbs. per sq. in.
Bearing parallel to the grain	1,500 " " " "
Shearing parallel to grain	270 " " " "
Longitudinal shear	170 " " " "

The power for swinging the pontoon must be sufficient to overcome various resistances; the principal ones of which are:

1. Resistance due to wind.
2. Resistance due to water friction.
3. Resistance due to inertia.

There are several additional factors involved in the theory of ship propelling. This theory is based on experiments performed under entirely different conditions and are hardly applicable to the swinging of a pontoon.

The resistance due to friction is given by the formula

$$R = fsV^2$$

in which s = wetted surface in square feet.
V = speed in knots.
f = a coefficient.

For smooth surfaces "f" is equal to 0.009; for rough surfaces twice as great.

As there are 3600 seconds per hour and a knot means 6080 feet we have

$$V = v\frac{3600}{6080}$$

in which "v" denotes the velocity in feet per second.

$$\text{and } R = fs\left(V\frac{3600}{6080}\right)^2.$$

Expressing this in terms of the angular velocity we have

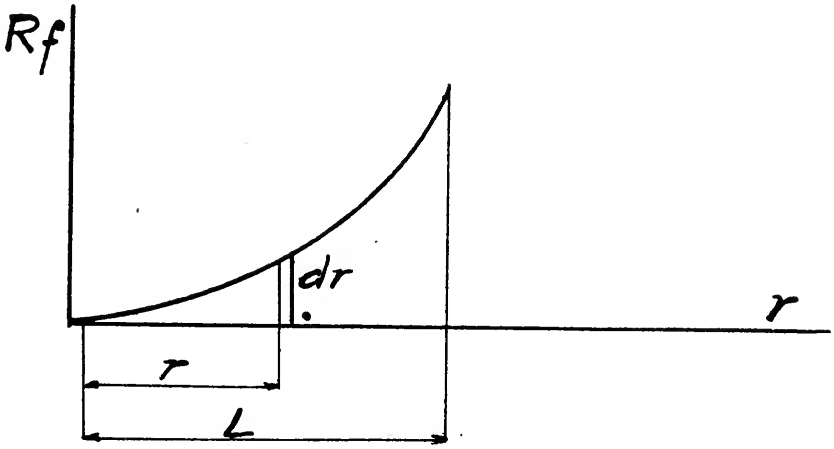
$$R_f = fs\left(\omega r\frac{3600}{6080}\right)^2$$

Since $w = \frac{2\pi rn}{r}$ radians, n = number of revolutions per second, this may be written.

$$R_f = fs\left(2\pi rn\,\frac{3600}{6080}\right)^2$$

rearranging we have $R_f = 4fs\pi^2n^2\,\dfrac{3600^2}{6080^2}\;r^2$

By considering the angular velocity constant "n" is constant and "R_f" and "r" are the only two variables in the equation—hence the resistance varies as the square of the radius.



By taking "R_f" and "r" as the axes of a rectangular coordinate system and letting "dr" represent a small increase in the radius, we have for a corresponding increase in the resistance: "Rdr" and the total resistance is, setting: $4fs\pi^2n^2\,\dfrac{3600^2}{6080^2} = C.$

$$R_f = C\int_0^L r^2dr = \frac{1}{3}CL^3$$

The center of gravity of this area is located at a distance from the origin and is obtained by taking moment about the origin "O". We then have

$$\frac{r}{3}CL^3 = C\int_0^L r^3dr = \frac{1}{4}CL^4$$

and $r. = \dfrac{3}{4}L$

The distance from the pivot pier to the pulling chain is 15/16L and the power to be applied at the chain to overcome the friction therefore is

$$\frac{\frac{1}{3}CL^3 \times \frac{3}{4}L}{\frac{15}{16}L} = \frac{4}{15}CL^3 ——— = P_f$$

To this frictional resistance should be added the friction due to the velocity of the stream when the bridge is operated against it. The velocity of the river at this point is approximately two knots and the resistance is

$$R_c = fsV^2$$

which may be considered constant without sensible error. The resultant of this force is applied at the center of the bridge and the chain pull will be

$$fsV^2 \frac{\frac{1}{2} L}{\frac{15}{16} L} = \frac{8}{15} fsV^2 ——— = P_c$$

The resistance due to inertia may be determined with sufficient accuracy by assuming the mass of the structure concentrated at a line through the center of the pontoon. We then have

$$R_1 = MA$$

in which M is the total mass
A is the acceleration
R_i the resistance due to inertia.

The resistance due to inertia at the hinge point is 0. The resistance due to inertia at the lock end is

$$R = ma = \frac{w}{g} . \frac{v}{t}$$

where w = weight per lin. ft. of bridge.
v = linear velocity in feet per second.
g = the constant 32.2 due to gravity.
t = time of acceleration.

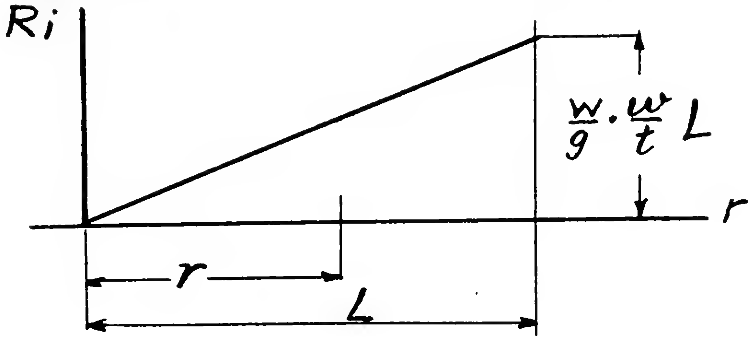
Expressing this relation in terms of the angular velocity "ω" we have since $v = \omega r$

$$R = \frac{w}{g} \cdot \frac{\omega r}{t}$$

This equation represents a straight line and the total resistance is obtained by integrating the expression $\frac{w}{g} \cdot \frac{\omega}{t} r$ between the limits L and O from which we obtain

$$R_i = \frac{1}{2} \frac{w}{g} \cdot \frac{\omega}{t} L^2 = C_1 L^2$$

which is the area of a triangle with base L and height $\frac{w}{g} . \frac{\omega}{t} L$



The center of gravity of this triangle is located at a distance 2/3 L from the origin and the force at the chain required to overcome this inertia is

$$C_1 L^2 \frac{\frac{2}{3} L}{\frac{15}{16} L} = \frac{32}{45} C_1 L^2 - - - = P_i$$

The resultant of the resistance due to wind is applied at the center of the structure and its magnitude varies with the exposed surface and the velocity and direction of the wind. Assuming a wind pressure of "P" pounds per square foot of exposed surface, we have $R_w = PA$ where "A" is the exposed surface. The force at the operating chain to overcome this resistance is

$$PA \cdot \frac{\frac{1}{2} L}{\frac{15}{16} L} = \frac{8}{15} PA - - - = P_w$$

The total force required at the chain to overcome the various resistances is

$$P = P_f + P_c + P_i + P_w$$

of these three forces P_x varies with the velocity. P_i varies with the acceleration; if therefore, the required maximum velocity is fixed and also the time of acceleration to reach this velocity is decided upon, the chain pull becomes a known quantity and the horsepower required can be determined.

To determine the power required, for swinging the 276 ft., 4 in. pontoon just described, it was assumed that it should swing open in three minutes. Fixing one-half minute for accelerating, one-half minute for retarding and constant velocity over two minutes, we have for the maximum velocity

$$2v + \frac{v}{2} \cdot \frac{1}{2} + \frac{v}{2} \cdot \frac{1}{2} = 400 \text{ ft. and } v = 160 \text{ ft. per minute.}$$

The 400 ft. represents the amount of chain passing over the drum during one opening of 90 degrees and for the acceleration we have

$V = a \times t$, from which $a = 320$ ft. per minute.

Substituting this velocity in the formulas previously developed and assuming the wind pressure at five pounds per square foot, it was found that the force "P" at the chain sums up to about 9,000 lbs. The horse power required assuming the efficiency of the machinery to be 65 per cent is

$$HP = \frac{9000 \times 160}{0.65 \times 33000} = 67$$

The pontoons are built on shore and launched before the floor and machinery is erected. The location of the construction platform and material yard is shown in the map of Fig. 1. Mr. N. Gregory, chief carpenter in charge of the construction, used the following method of launching the Prairie du Chien pontoon. The pontoon was built on a platform located near the east shore of the Mississippi River. When the pontoon was completed for launching, skidways were built about twenty feet apart, as shown in Fig. 30a and b. These skidways were built on a slope of $1\frac{1}{2}$ inch in 12 inches, and extend out into the river supported on piles cut below the surface so that the pontoon is practically floating before it leaves the skidways. These skidways were lined with strips of hardwood on the top to provide a smooth sliding surface. Hardwood blocks about 8 feet long were placed at suitable intervals to act as bearing blocks between the skidways and the pontoon. Above the pontoon, at the side farthest away from the shore, 4 capstans marked "C" in Fig. 30b are placed in front of piles marked "P." The capstans are securely tied to the piles by cables or chains. Steel cables marked "S" in Figs. 30a and 30b were thrown around the pontoon and connected to the capstans. At the center of the deck of the pontoon short pieces of manila rope marked "R" in the figures are inserted between the steel cables. The cables between the capstans and the pontoon are then tightened as much as possible to keep the pontoon from sliding before it is resting on all the skidways. The bents or cribs upon which the pontoon was built are then undermined so that the pontoon gradually settles to a full bearing on the skidways. When a full bearing of the skidways has been obtained and everything is ready, a man with an axe is stationed on the deck of the pontoon at each cable. At the signal given by the man in charge, the four pieces of manila rope inserted between the steel cables are cut simultaneously by these men and the pontoon slides slowly into the river.

Fig. 27 shows a photograph of the new Prairie Du Chien Pontoon taken just before it was ready to launch. Fig. 32 shows the hull of one of the old 400-ft. pontoons.

Fig. 31 shows the drydock used in repairing these pontoons.

It consists of timber frames lined with sheathing. The edge of this drydock is made to fit the outside of the pontoon and is lined with heavy canvas and cotton waste to make the joint between the drydock and the pontoon as watertight as practicable. It is, of course, impossible to make this drydock entirely waterproof, and provision must be made for pumping the water constantly while the men are working in the dock.

The design of the west channel pontoon just described was in direct charge of the writer under direction of Mr. H. C. Lothholz, Engineer of Design, and Mr. C. F. Loweth, Chief Engineer of the C. M. & St. P. Ry.

Estimates for a concrete structure were made and compared favorably with the estimates for the wooden structure, but on account of the greater difficulties in construction and the comparatively shallow water during most of the season, the project was abandoned. A concrete pontoon would weigh considerably more than a timber structure and consequently the greater displacement would require either a wider or a deeper structure. It would seem, however, that at certain locations a concrete scow used as a pontoon bridge should prove both economical and efficient and be worthy of consideration.

DISCUSSION

At the conclusion of the paper by Mr. Hansen, the Secretary read from the Transactions of the American Society of Civil Engineers, Vol. XIII, page 67 (1884) extracts from the paper by Mr. John Lawler, with discussion by Mr. D. J. Whittemore, presented at the annual convention of the American Society of Civil Engineers at St. Paul, Minn., June 20, 1883, as follows:*

Mr. Lawler

> "The structure throughout is of ordinary piling, except across the navigable portions of the channels, which are covered by the pontoon draws. Each of these draws is a single float, 30 feet wide at the bottom, 6 feet deep, and 41 feet on deck, and 408 feet in length. . . . The track is regulated to the varying stages of the river by a system of blocking, confined in a frame and adjusted by means of hydraulic jacks. It may be observed that the range of variation between high and low water at this point is 22 feet. . . .
>
> The draw is operated by a steam engine of about 20 horsepower, which communicates motion to a pulling chain passing over a drum, and stretching along the bed of the river, to suitable points above and below the draw, where it is securely fastened. . . . The draw, when in position for the passage

*The volume referred to, of the Transactions of the American Society of Civil Engineers, contains a number of illustrations having an important bearing on the subject, to which the reader is referred.

of trains, lies across the current of the stream at about a right angle, and when opened for the passage of river craft, comes to a rest parallel with the thread of the stream. The time occupied in opening or closing the draw is three minutes. The ends of each draw are adjustable to the approaches by trusses, 30 feet in length, composed of iron and of timber, by means of which the track upon the pontoon is securely connected with the permanent track. At each end of the draw, shear booms rest on piers driven for the purpose, and extend at an easy angle to either shore, by means of which the largest rafts are safely guided through the draw-opening without the necessity of uncoupling.

The structure was built at about one-sixth of the estimated cost of an ordinary pivot bridge at the same point. . . .

The adjustments to the various levels of the water are made by the men who are otherwise necessarily employed upon the bridge, without the slightest hindrance to the trains, and, of course, without the slightest additional expense. The track is so adjusted that just previous to the passage of the train the level of the pontoon track is slightly above the level of the permanent track, so that the weight of the engine, in entering upon the pontoon draw, brings the pontoon to a perfect level. . . .

The pontoon or draw part of the bridge gradually settles under the passage of a train about five (5) inches, but to an ordinary observer, or to the passengers on the train, this settling is not noticeable, on account of the manner in which the ends of the draw are connected with the permanent approaches of the bridge.

Mr. Whittemore.

Some of the older members present will call to mind that during the years 1848 to 1850 the Vermont and Canada and the Northern New York railroads were under construction. . . . When these lines were nearing completion it became necessary to devise some way to join them at the crossing of the outlet of Lake Champlain at Rouse's Point. A pontoon 303 feet long, about 30 feet wide, and 7 feet high, was constructed, and when it was launched, July 4, 1851, I displayed sufficient lack of wisdom to be on board. The lake on the line of railway at this point is a little over one mile wide. Pile and timber approaches were built from each shore until a space equal to the length of the pontoon intervened. Suitable aprons for adjustment of track to the varying height of water were made at the end of each approach. For steam power to operate the pontoon there was used a dismantled locomotive. . . . This pontoon performed its duty until April 1st, 1868, and without accident of any kind, so I am informed. . . .

Mr. Lawler's pontoon, however, is so radically different from any built previously that it can be well said that Mr. Lawler is not only the designer and builder of it, but its originator. He constructed his pontoon 100 feet longer than the one at Rouse's Point. He arranges the approaches so as to adjust the track to a rise and fall of water of 20 feet. In Lake Champlain the extreme rise and fall hardly ever exceed 7 feet, if I remember rightly. There is but a slight current at the outlet of that lake, while Mr. Lawler operates his pontoon against a very rapid current.

Walter S. Lacher, ASSOC. W. S. E.: The question naturally arises as to the cost of a structure of this kind as compared to the more common types of bridges but the paper does not bring this out. An article describing the west structure which was completed in 1914 and which was published about that time, brought out some correspondence on just this point from engineers in various parts of the country. Because this is an unusual type of structure it would be interesting to know just why it was selected. Mr. Lawler's paper is very interesting, however, the statement that the original pontoon bridge was perfectly level when the trains were on it must be taken with a grain of salt. That is a condition which we do not expect of the best design today. The deflections are entirely apparent to anyone who is on a bridge of this kind when a train is passing over it. It must be said, however, that there is an immense difference between the new 250 foot pontoon on the east side of the river and the old 400 foot structure on the west side.

I had a very interesting experience while in the hold of the old pontoon on the west side of this bridge that was not exactly what I had expected. The deformations of the barge accompanying the deflection produce a very loud cracking of the timbers. This cracking is loudest in the portion of the structure directly under the locomotive and passes across the bridge with it. It is an experience that is not readily forgotten.

I have a question about the wave mentioned on page 16. It says that the wave length is equal to the length of the pontoon. As the pontoon is 209 feet long, this would give a wave of that length but only two feet high which seems decidedly unusual.

Figure 31 shows a drawing of the dry dock which is used frequently for calking in the maintenance of the pontoon. As you see, it is simply a box which is sunk under one side of the barge and as the water is pumped out it presses up against the planking and permits a calker to work on the side planks of the pontoon and for a slight distance on the bottom planks. When I visited this structure the bridge tender told me of an improved form of dry dock which had been built several years ago to permit of the calking of the bottom planks at any point on the under side of the barge. It consisted simply of a square wooden box open at the top and

connected at one side with a long wooden pipe or tunnel by means of which the calker could descend or crawl into the dry dock after it was in bearing on the bottom planks and the water had been pumped out. The device was entirely successful, but no man was ever found who had the courage to go into it.

F. G. Vent, M. W. S. E.: The noises like gun shots which are heard in the hulk of this pontoon during the passage of an engine, are very interesting to note and are quite easily accounted for.

This pontoon was built in 1900 from details which were nearly a duplicate of the details of the old pontoon which it was to replace.

We could find no record of how this old pontoon was designed, and concluded it was designed principally by good judgment and from data from boat hulls.

The writer made calculations for strength against moments, shears, bouyancy and a certain amount of wind, to satisfy himself that the design was of ample strength, but did not make any calculations upon deflections. The hull was necessarily very shallow for the great length (405 ft.) and the principal source of strength to resist moments were the three lines of longitudinal bulkheads, one of 12 in. by 12 in. and two of 8 in. by 16 in. timber laid flat upon each other and joined together by drift bolts and 2 in. diameter wooden tree-nails. Due to the excessive shallowness of these bulkheads, which act like long longitudinal girders, they deflect excessively and this excessive deflection causes quite a longitudinal slipping between the various layers of timbers joined together with the drift bolts and tree-nails. Hence the cracking noises like gun shots, due to the longitudinal slipping of these timbers and consequent straining and adjustment of the tree-nails and drift bolts, much the same as the squeaking in the soles of a pair of pegged shoes and more noticeable with the increasing age of the structure. An an illustration of the rapidity with which a pontoon can be constructed, in 1906 one of similar type was constructed for the C. M. & St. P. crossing of the Missouri River at Chamberlain, S. D., and thirty days after making the requisitions for the material, the writer received a photograph of the first train crossing the bridge.

Henry Goldmark, M. W. S. E. (By Letter): This valuable paper has proved of special interest to the writer, as he has recently designed a similar bridge for carrying railway and highway traffic across the Panama Canal.

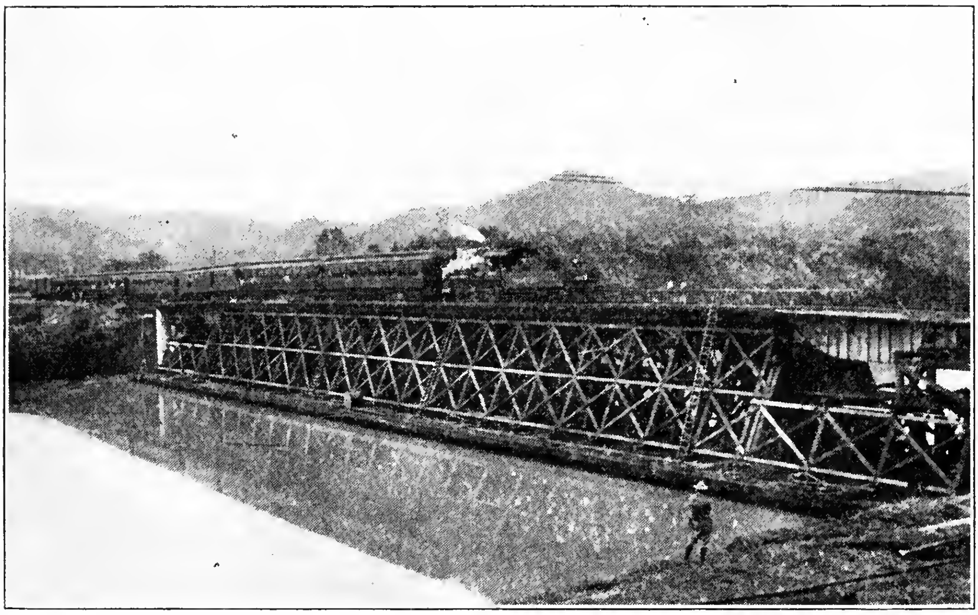
The design adopted was based largely on the plans for some of the later Mississippi River bridges, copies of which were kindly furnished to the Canal authorities by Mr. C. F. Loweth, Chief Engineer of the Chicago, Milwaukee and St. Paul Railway. Owing in part to differences in local conditions the Panama pontoon differs in some essential features from the older design. It was therefore thought that a brief account of its construction might be of interest to members of the Society.

The bridge crosses the canal near the village of Paraiso, a short distance north of the locks at Pedro Miguel near the end of the Culebra cut.

Its location is close to the site of the timber trestle which carried the main line of the Panama Railroad over the canal line for many years, since, under the French regime, it became necessary to remove the tracks from the canal axis at what is now the deepest part of Gaillard Cut near the village of Culebra.

As is quite generally known the main line of the Railway has now been moved entirely to the East side of the Canal and most of the settlements on the West bank abandoned.

The pontoon bridge, therefore, serves merely to connect the new line near Pedro Miguel with a remnant of the old main line, a few



Pontoon Bridge Panama Canal, at Paraiso.

miles long, extending to the villages of Las Cascadas, Empire and Culebra.

As the principal military camps have so far been retained on the West bank, the maintenance of the railroad connection seemed imperative, at least for the present. The permanent army posts will, however, beyond much question, be built on the West side of the channel and hence a quasi-temporary structure seemed more suitable than either a tunnel under the canal or a steel bridge at one of the locks or at some other point. The floating type was therefore selected as being less expensive, while likely to fulfill all the necessary requirements.

The general plan of the bridge is shown on the accompanying drawing. Its clear span is 300 ft., corresponding to the bottom width

of the Canal channel at this point. When in an open position it is kept in a recess excavated in the East bank. There is a concrete pier at each end founded on solid rock, the expense of the piers forming a large part of the total cost. The variation in the water level, which corresponds to the elevation of Gatun lake is comparatively small, ranging from a maximum of +87 above sea level to a minimum of about +81. The small variation made it possible to place the track at a fixed height above the deck of the pontoon, taking care of the different stages of the water automatically by means of the approach girders.

The pontoon is 378 ft. long over all; 55 ft. wide and 6 ft. 3 in. deep along the centre line. Its construction agrees quite closely with that of the Mississippi River bridges.

The frames are spaced 24 in. between centres. The floor timbers and rake timbers being 4 in. by 12 in. and the deck beams 4 in. by 10 in. Under the trestle sills, at intervals of 14 in., there are trussed frames consisting of three ordinary frames bolted together and having 1⅜ in. steel rods as diagonals.

Six solid longitudinal bulkheads of 8 in. timbers extend from end to end of the pontoon.

The sheathing consists of 4 in. by 10 in. and the deck of 3 in. by 10 in. planks calked and pitched. The deck is covered with an asphalt coating.

The height of the trestle, 33 ft. above the bottom of the pontoon, was fixed by the elevation of the railroad track on each bank and the requirement of moderate gradients. The bents follow common railroad practice, having six 12 in. by 12 in. posts, 12 in. by 14 in. caps, and a 12 in. by 14 in. sill.

The outer and intermediate posts have a heavy batter, distributing the weight over the whole width of the hull.

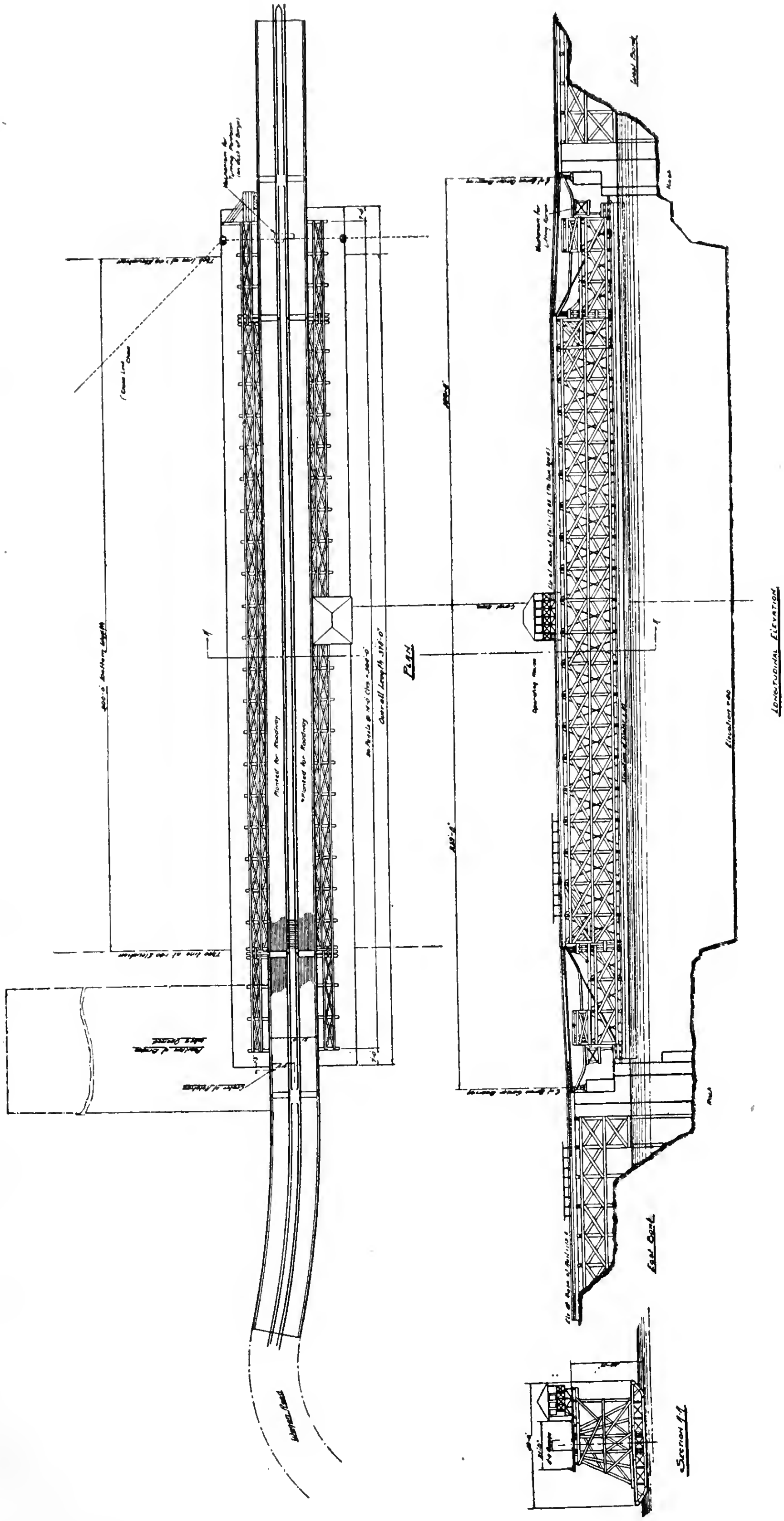
As the pontoon has little longitudinal stiffness, the trestle was designed to act as a stiffening truss to withstand the heavy bending moments and shears that prevail under a moving train.

The track stringers, two 10 in. by 16 in. and one 8 in. by 16 in. under each rail, were fitted with plate splices, so as to form a continuous top chord, capable of withstanding tensile as well as compressive stress. At the bottom of the pontoon, a similar continuous chord was provided. The trestle posts act as vertical members of the truss, while the diagonals consist of 2-in. steel rods, there being two rods per panel in each direction in each truss.

The stresses in the trusses were computed in essentially the same manner as that described in Mr. Hansen's paper.

The structure is stiffened further by the timber longitudinal and diagonal bracing along the batter posts, as well as by the heavy longitudinal bulkheads.

Douglas fir and long leaf yellow pine were used, all surfaces being heavily coated with Avenarius Carbolineum applied cold with a brush.



Pontoon Bridge, Panama Canal.

The apron girders at each end are about 64 ft. long and formed a portion of the spare parts which were provided for making repairs to the mitering lockgates in case of accident.

When the bridge is to be turned, these girders are supported on blocking after being lifted clear of the piers by a mechanism near the end of the pontoon, consisting essentially of an electrical moved toggle.

The pivot about which the bridge revolves consists of a steel tube 22 in. in diameter, filled with concrete, fastened to the east pier. There is a heavy automatic latch at each pier and a buffer on the west pier.

The bridge is turned by means of a 1-in. anchor chain fastened at each bank and lying on the bottom of the canal when the bridge is open.

It passes around the "wild cat" of an electrically driven windlass on the deck of the pontoon near the west end. A separate power barge is not used.

The rail latches, etc., are similar to those used on the Mississippi River bridges.

The mechanism for lifting the apron girders, for turning the bridge and for operating the rail lift and latches, are operated from a central panel in a control house at the rail level. It takes about ten minutes to turn the bridge and about forty-five minutes to make a complete operation, including unlocking, opening, closing and re-locking.

The bridge has been entirely successful in operation, showing but little deformation and no excessive immersion under moving loads. A little difficulty has at times been encountered in adjusting the end blocking rapidly, owing to frequent variations in the water level, due to lockages in the Pedro Miguel lock, a short distance below the bridge.

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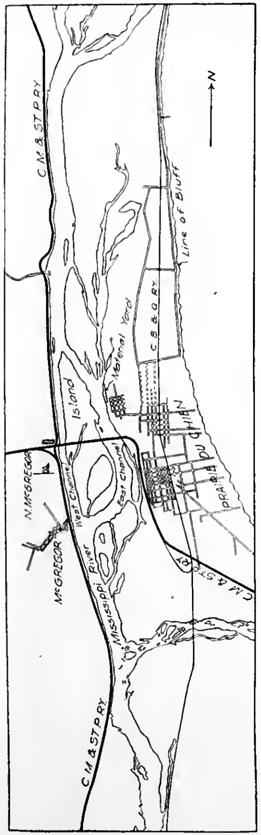
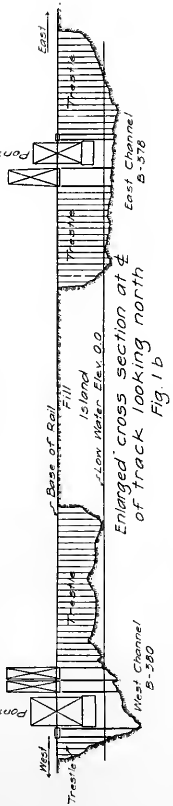
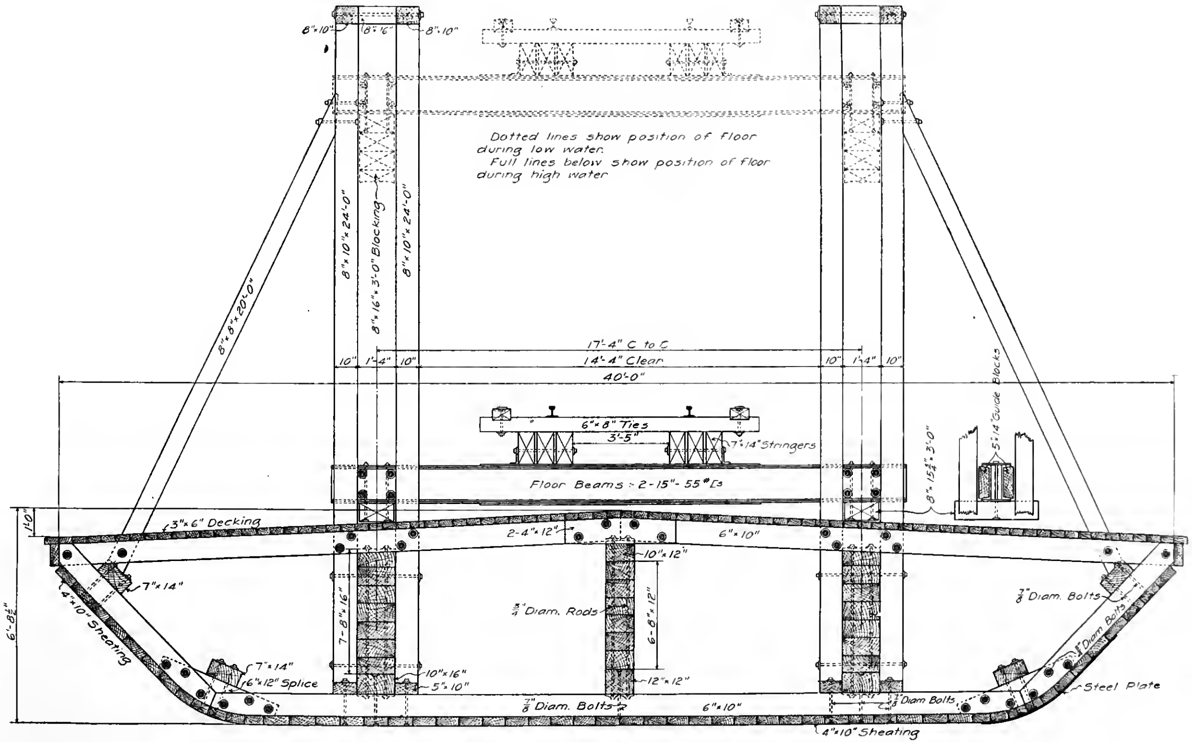
Hansen—Ry. Pontoon Bridge.



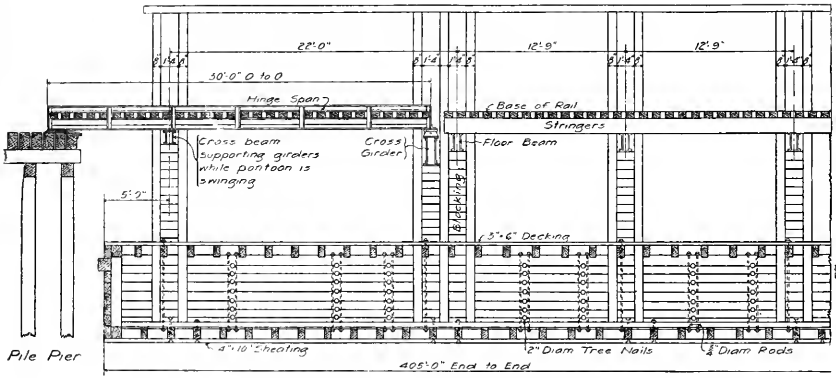
Location Plan
Fig. 1a



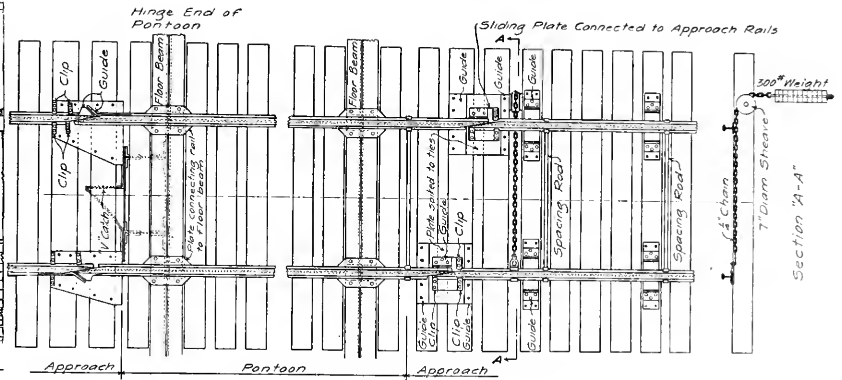
Enlarged cross section at ℄ of track looking north
Fig. 1 b



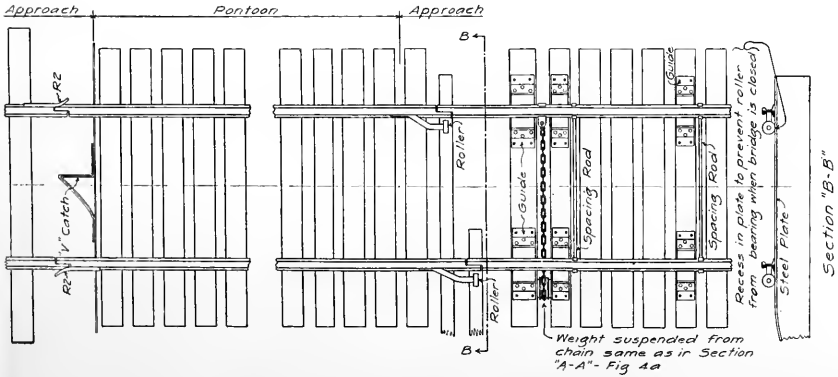
Cross Section
Fig 2



Longitudinal Section Through Center
Fig. 3



General Plan of Rail Joints New Pontoon
Fig 4a



General Plan of Rail Joints Old Pontoon
Fig 4

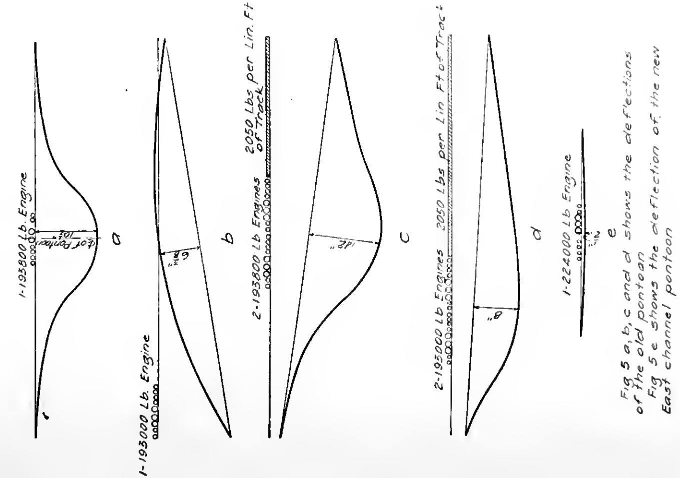


Fig 5

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Hansen—Ry. Pontoon Bridge.

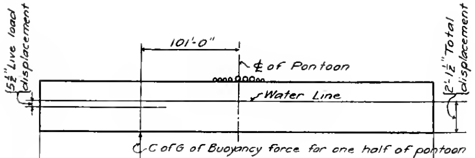


Fig. 6a

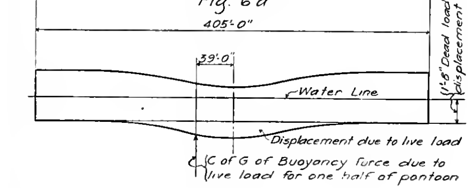


Fig 6 b

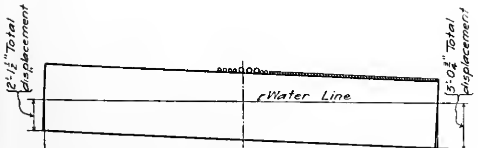


Fig. 7a

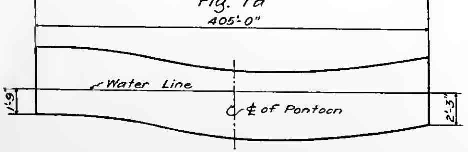


Fig. 7b

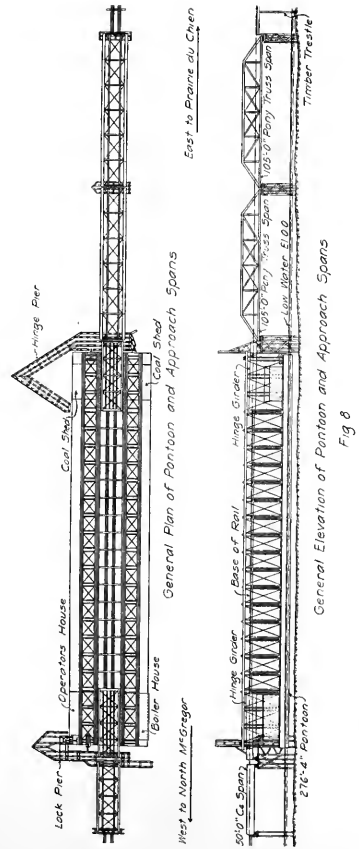
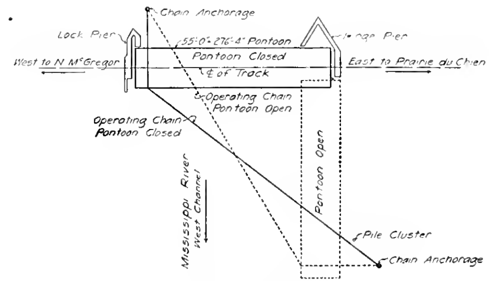
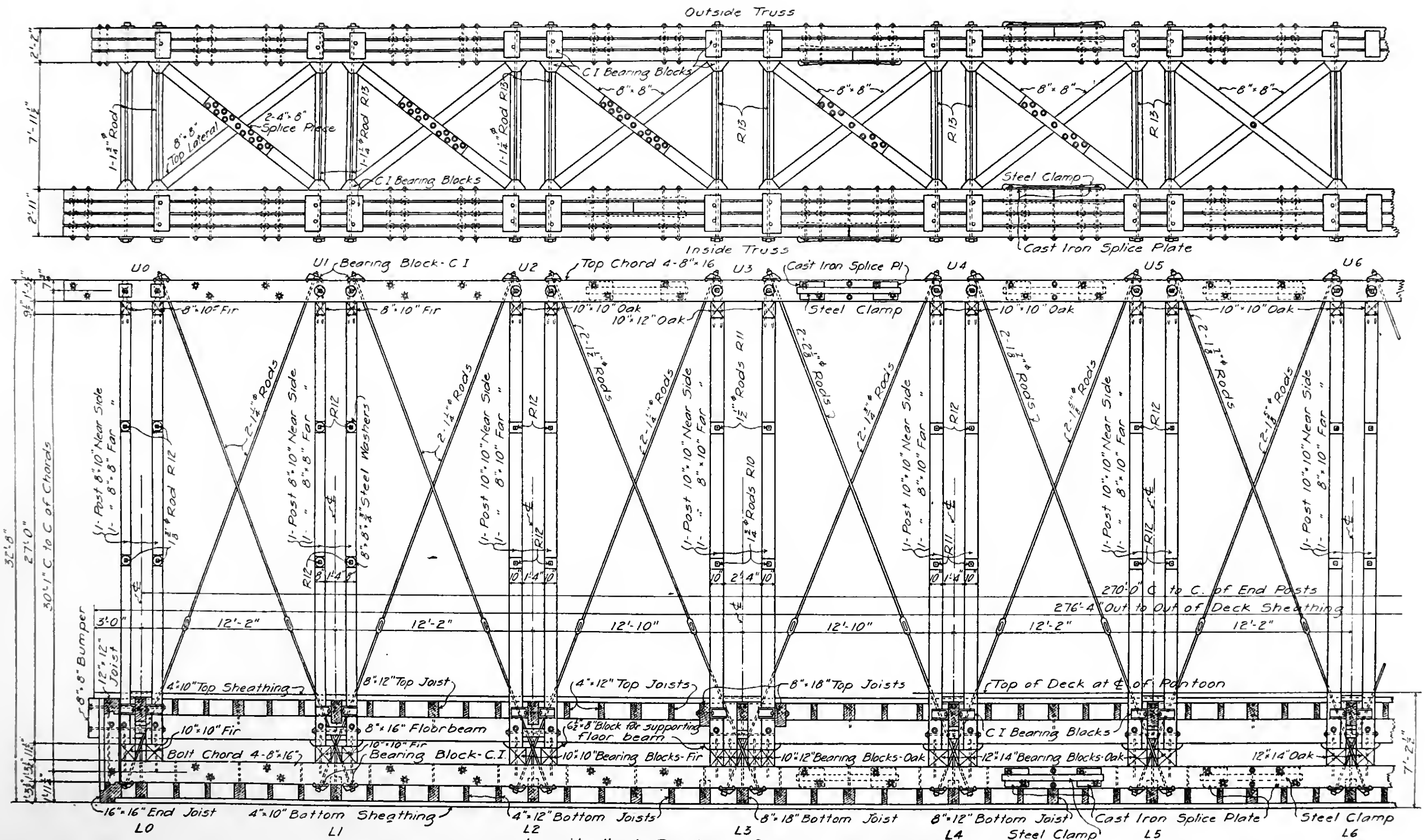


Fig 8



General Layout
Showing operating chain
Fig 9



Longitudinal Section Showing Part
Elevation of Inside Truss
Fig. 10

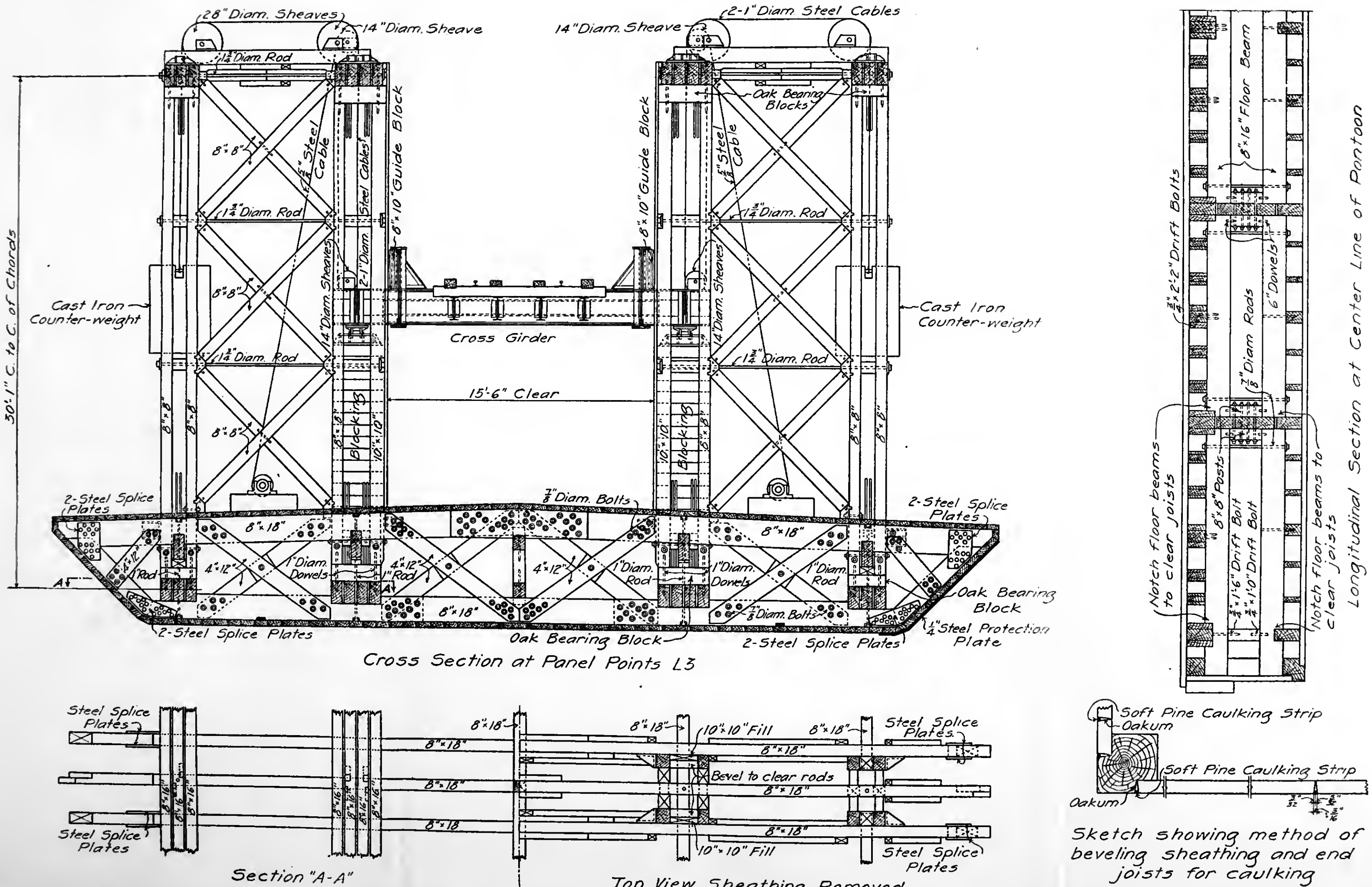
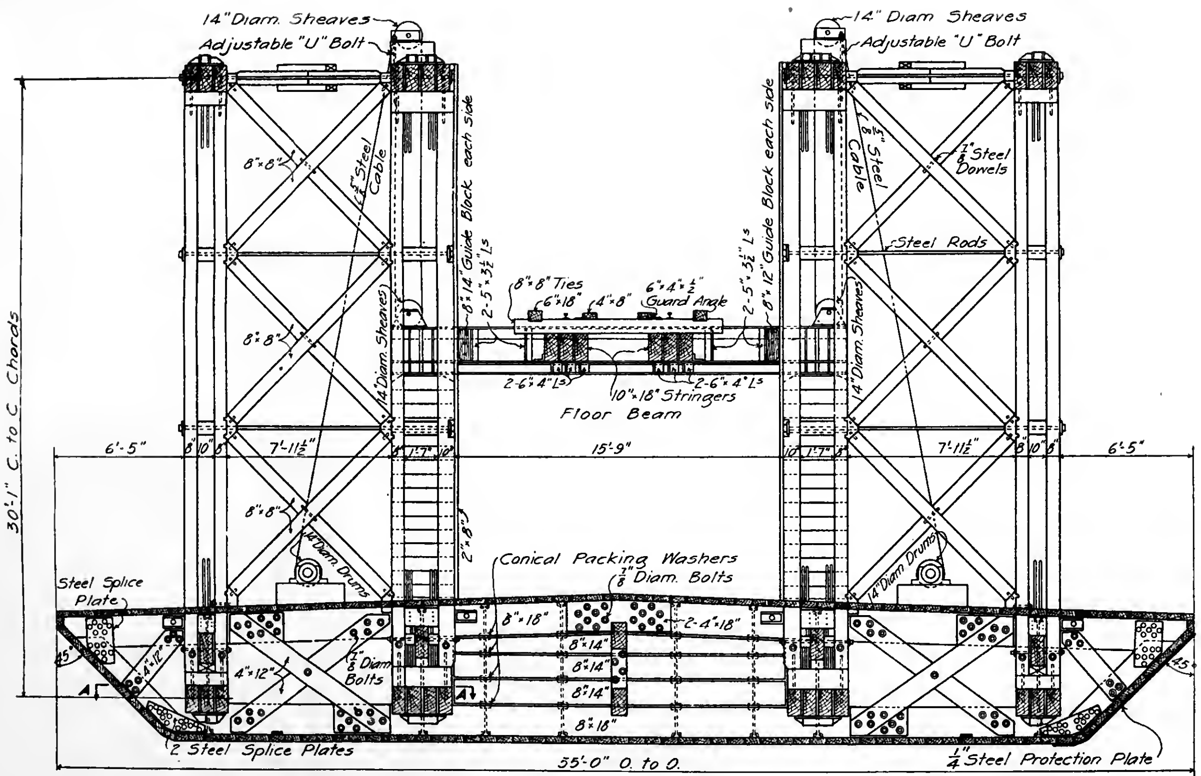
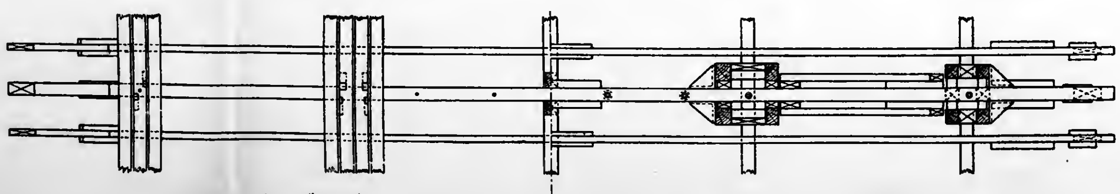

28" Diam. Sheaves
14" Diam. Sheave
14" Diam. Sheave
2-1" Diam. Steel Cables
1¾" Diam. Rod
Oak Bearing Blocks
8"×8"
¾" Steel Cable
2-1" Diam. Steel Cables
6"×10" Guide Block
8"×10" Guide Block
⅝" Steel Cable
1¾" Diam. Rod
14" Diam. Sheaves
Cast Iron Counter-weight
Cross Girder
15'-6" Clear
30'-1" C. to C. of Chords
Blocking
10"×10"
2-Steel Splice Plates
⅞" Diam. Bolts
8"×18"
4"×12"
1" Rod
1" Diam. Dowels
1" Diam. Rod
Oak Bearing Block
¼" Steel Protection Plate
Cross Section at Panel Points L3
8"×16" Floor Beam
¾"×2'-2" Drift Bolts
6" Dowels
⅞" Diam. Rods
8"×8" Posts
¾"×1'-6" Drift Bolt
¾"×1'-0" Drift Bolt
Notch floor beams to clear joists
Longitudinal Section at Center Line of Pontoon
Steel Splice Plates
8"×16"
Section "A-A"
10"×10" Fill
Bevel to clear rods
Top View Sheathing Removed
Soft Pine Caulking Strip
Oakum
Sketch showing method of beveling sheathing and end joists for caulking

Fig. 11



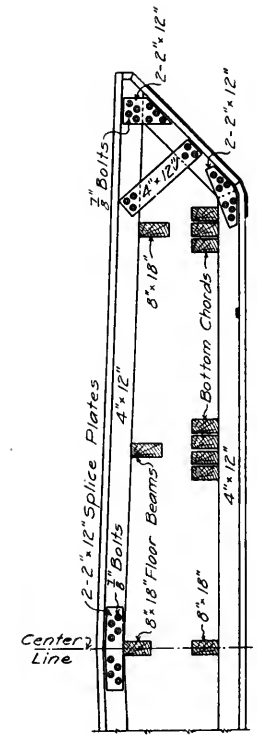
Cross Section at Intermediate Panel Points



Section "A-A"

Top View Sheathing Removed

Fig. 12



Typical Cross Section between Panel Points

Fig. 13

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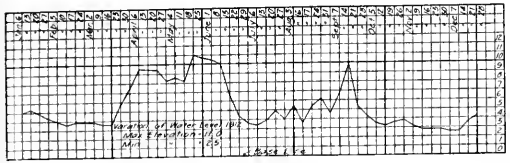
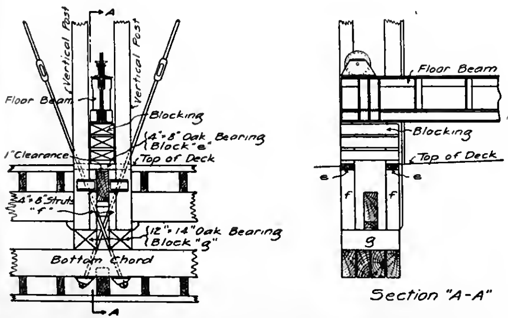
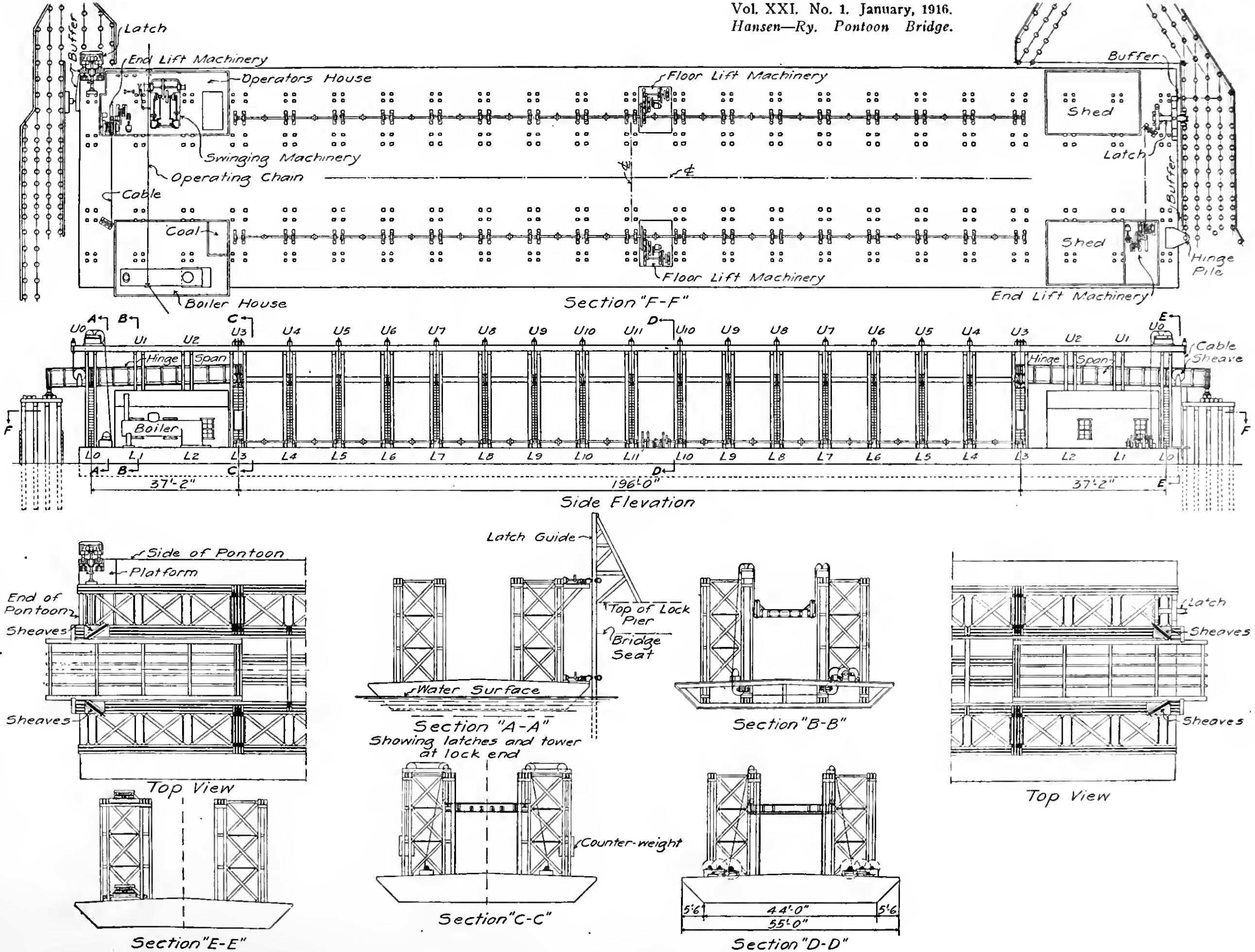


Fig 14



Sketch Showing Arrangement for Transferring the Live Load to the Trusses

Fig. 15a



General Plan of Operating Machinery

Fig. 15

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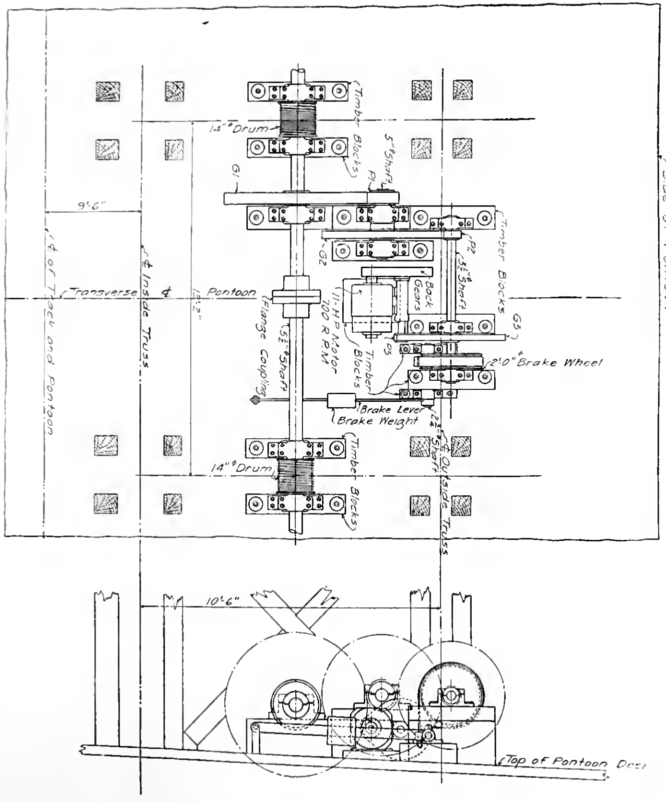
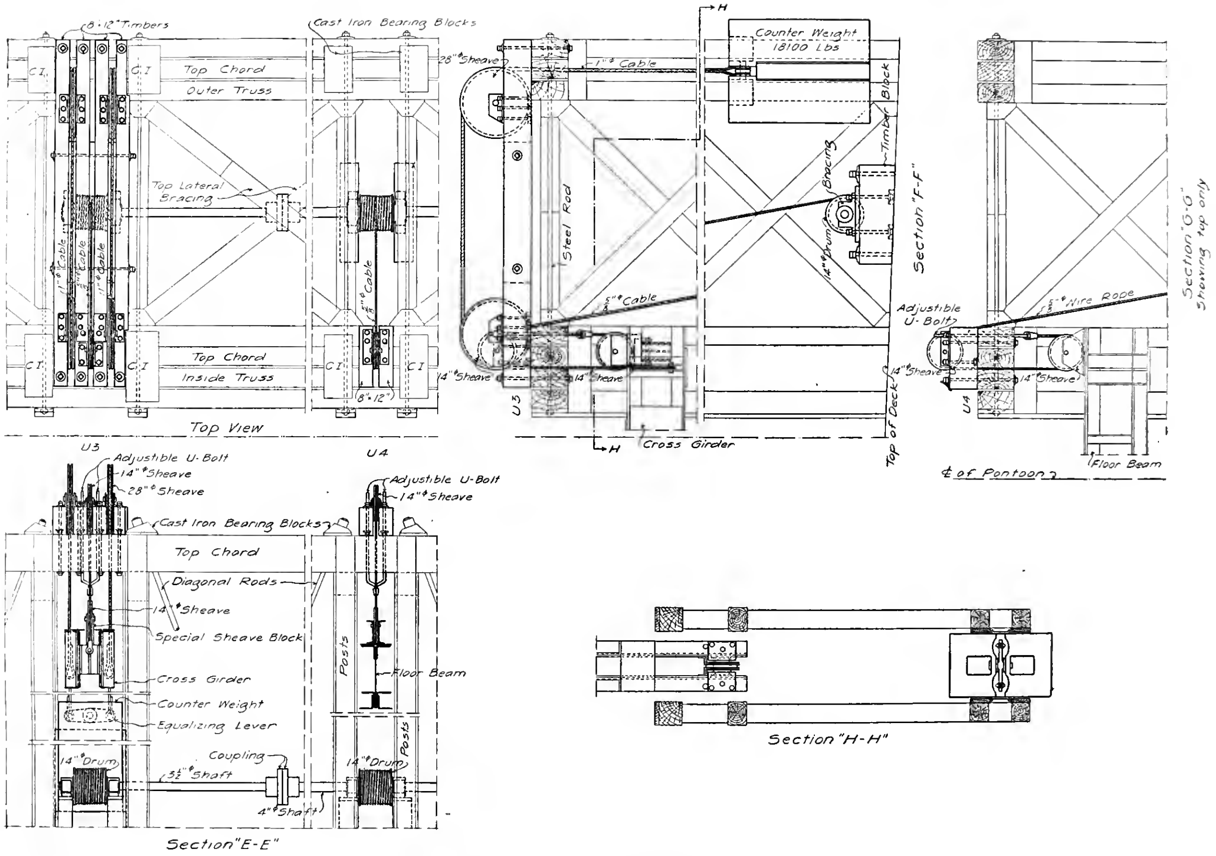
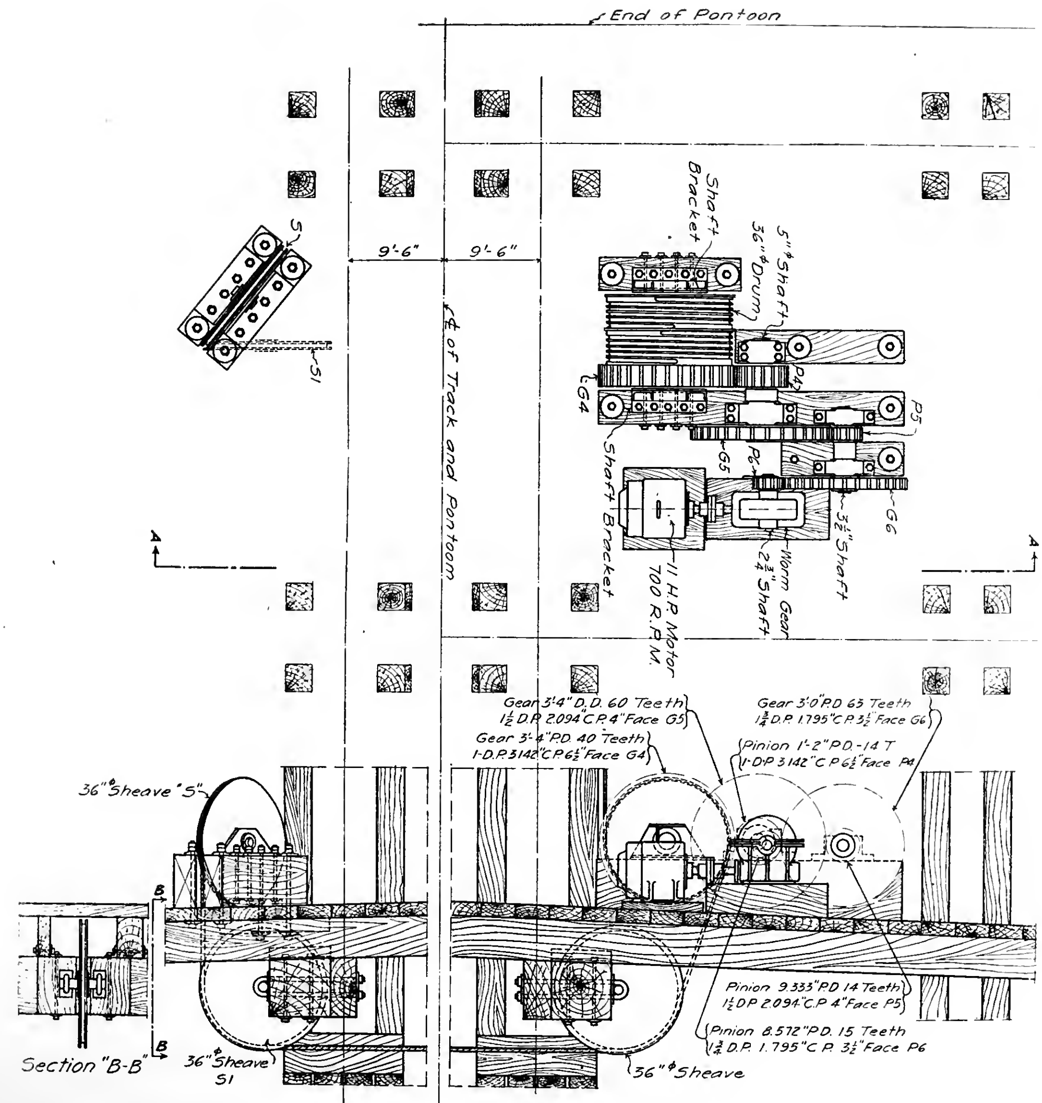


Detail Plan of Floor Lift Machinery
Fig. 16



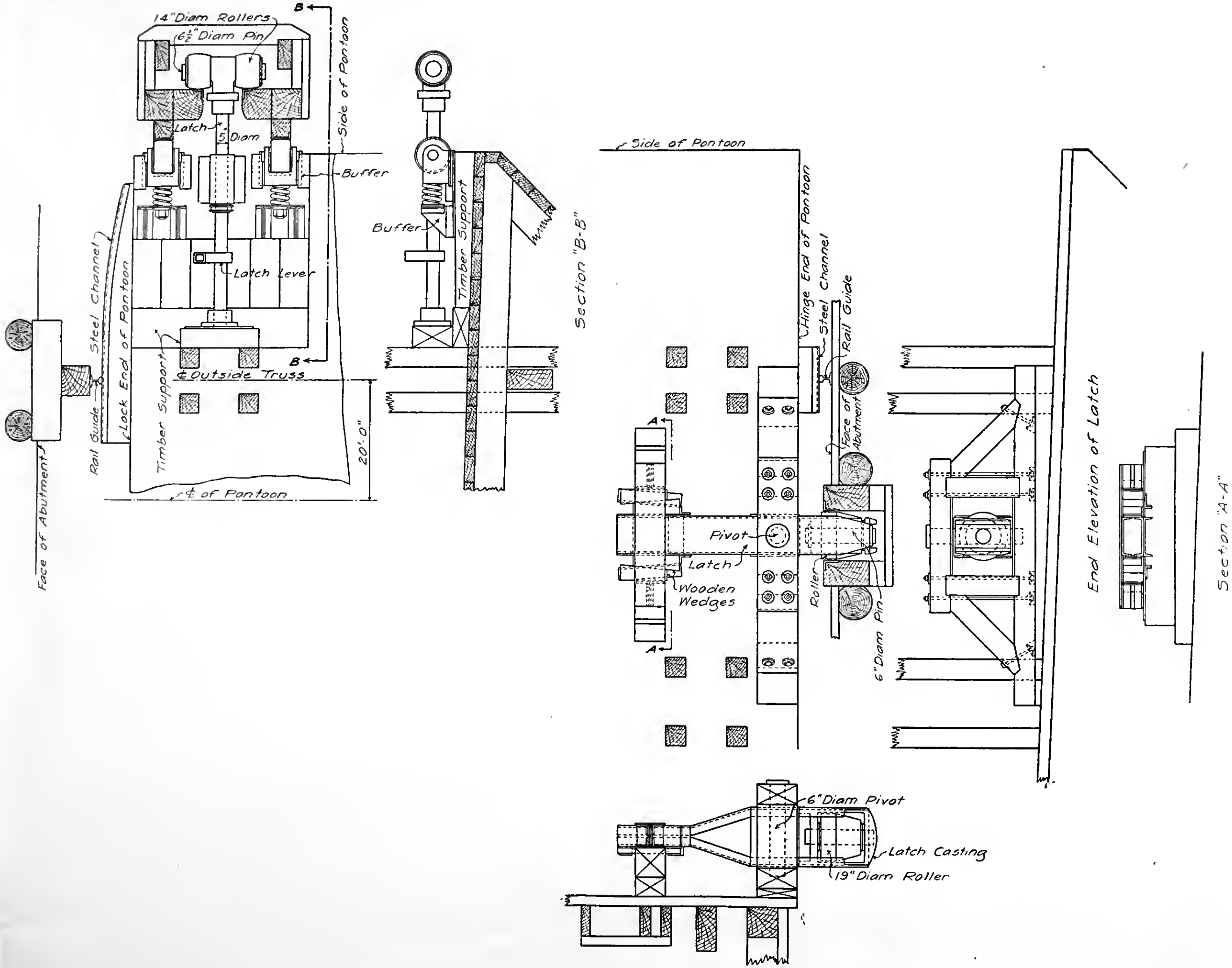
Details of Floor Lift Cables and Sheaves

Fig. 16a



Detail Plan of End Lift Machinery

Fig. 17



Details of End Latches and Buffers

Fig. 17a

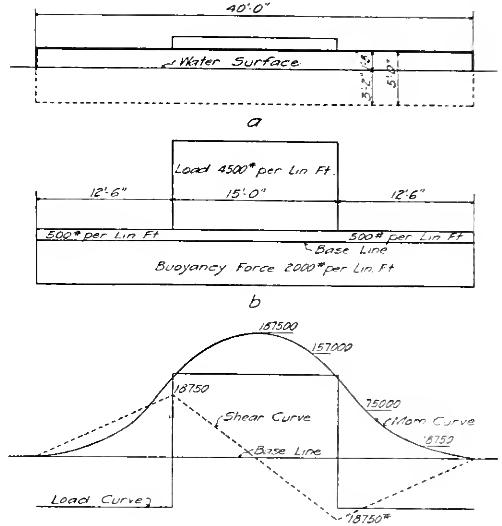


Fig 18

Fig. 19

Fig. 20

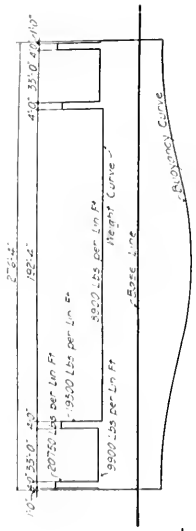


Fig 22 a

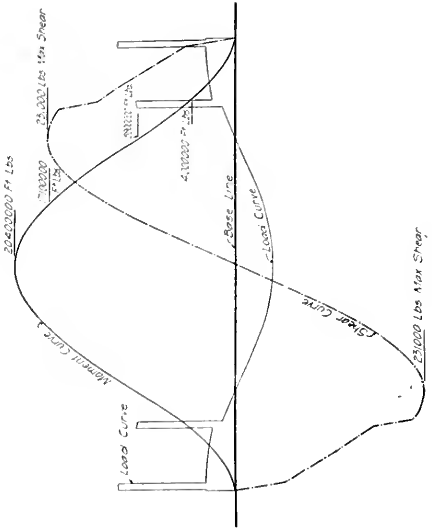


Fig 22 b

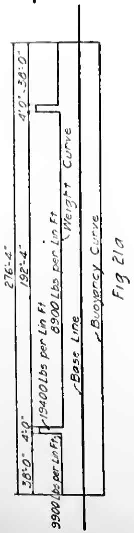


Fig 21 a

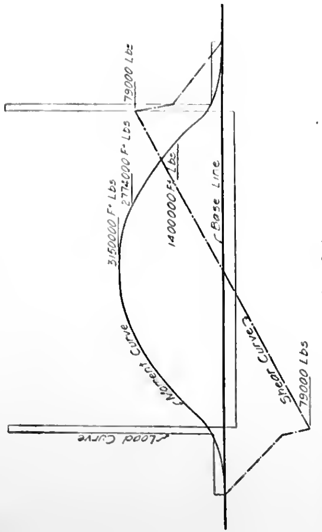


Fig 21 b

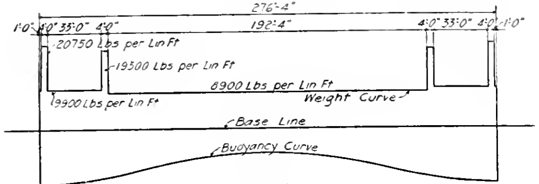


Fig 23 a

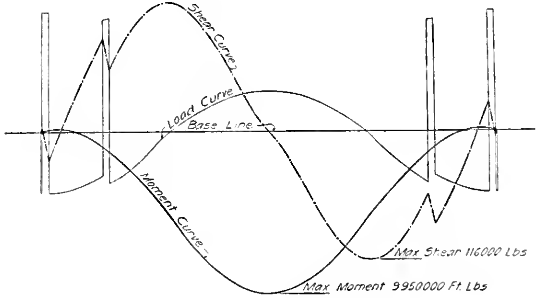
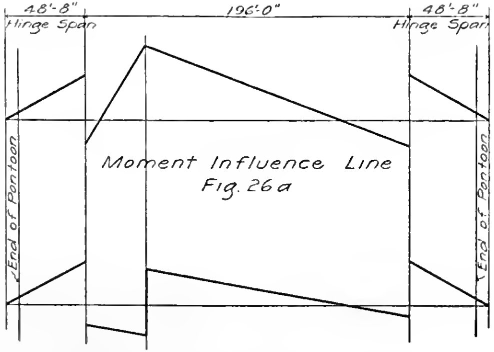


Fig 23 b



Moment Influence Line
Fig. 26 a

Shear Influence Line
Fig. 26 b

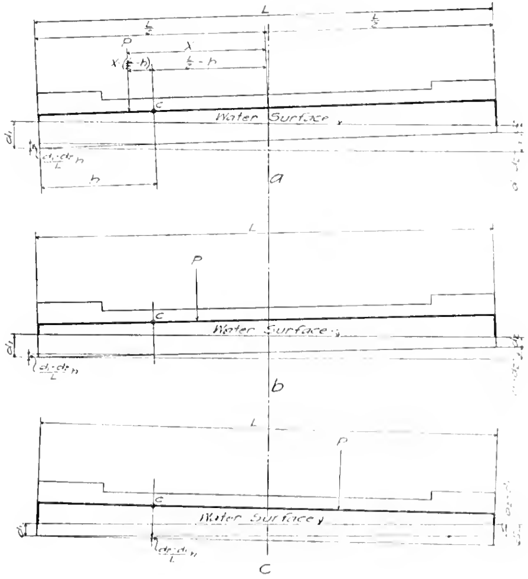
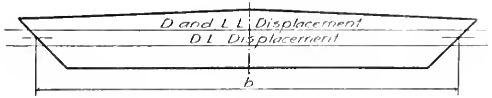
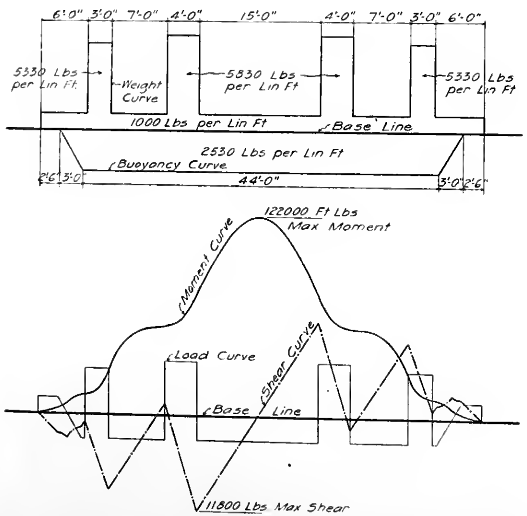


Fig. 25



Cross Section Showing Average Width "b"
Fig. 24

Fig. 27



Transverse Shear and Moment Diagrams

Fig. 28

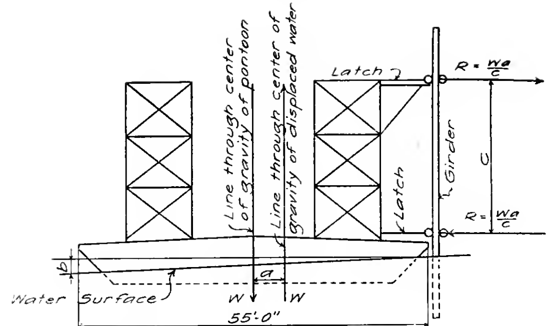
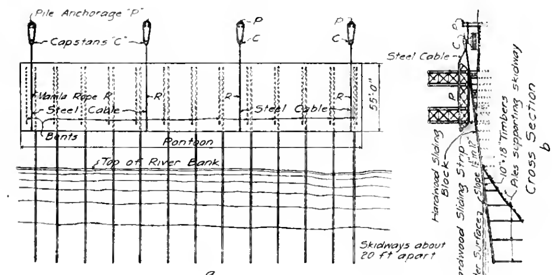


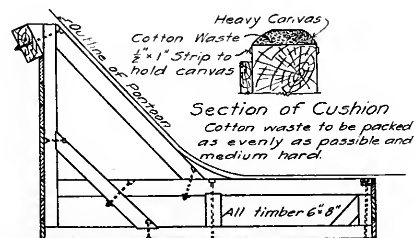
Diagram Showing Reactions at Latches due to Waves

Fig. 29



Sketch Showing Method of Launching

Fig 30



Dry Dock used for Repairing Pontoons

Fig. 31

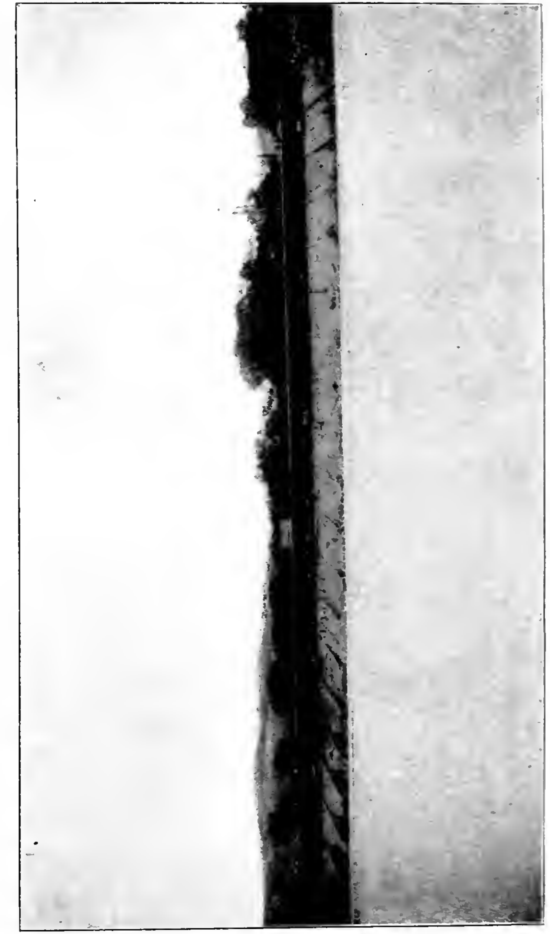


Fig. 32

REGULATION OF PUBLIC UTILITIES

LEONARD A. BUSBY.*

Presented at a Joint Meeting, Electrical Section, W. S. E., and Chicago Section, A. I. E. E., November 22, 1915.

My purpose is to speak about the present status of the regulation of certain public utilities. I am not here to attack or defend the regulation of these utilities. I have no "universal sovereign" remedy to offer, either to the regulators or to the regulated. I have no new theories to present. But I do wish to discuss certain phases of the situation which confronts us. What I have to say will apply mostly to electric railways in the larger cities of this country, although applicable to a greater or less extent, to other public utilities.

With the exception of steam railroads, electric railways are by far the most important of the public utilities that are now attempting to meet problems of regulation. Railroads have been subject to varying forms of governmental control, through constitutions and statutes, since the early seventies. It is only within the last decade that electric railways in our larger cities, including street railways, elevated roads, and more recently, lines operated in subways, have fallen heir to about all the ills with reference to regulation, that could affect any utility.

No other utility renders a service of such vital importance to the millions of people living in our large cities as the utility furnishing transportation; no other utility renders a service so personal or so vitally necessary to the welfare, growth and development of the community.

STREET RAILWAY REGULATION A PARTICULARLY DIFFICULT PROBLEM.

The companies which supply our cities with gas, electric light and telephones render an invaluable service. This service, however, is neither so universally used, nor so vitally necessary to the welfare of the community as transportation; nor does the regulation of these utilities present the difficulties involved in the regulation of street railway service.

In this city we do not hear much about the regulation of the gas company or the telephone company, except as to rates, and then the agitation usually precedes a mayoralty campaign. Rates for gas, light and telephone service are not subject to regulation oftener than once in five years. Service bills of these companies are presented only once a month, and while these bills occasionally cause a slight irritation they are not, except at long intervals, the basis of a demand for regulation.

So far as the public is concerned, the use of the service furnished by these utilities is a matter of lighting the gas, turning the

*President, Chicago Surface Lines.

electric light switch, or taking up the receiver of the telephone. In severe weather the gas pipes may freeze, occasionally a light circuit may go out for a few minutes, and now and then we get a busy signal over the telephone; and these matters may be largely attributed to natural causes, unavoidable accident, or the perversity of some other subscriber,—but as a rule, the main issue with reference to the service furnished by these utilities is a question of rates, and the agitation on that question is infrequent, and usually synchronized with some political activity.

Not so with the companies furnishing transportation in large cities. In nearly every large city in this country the traction question at some time has been made a political football, and in no city to a greater extent than in Chicago.

For more than twenty years prior to the last municipal election the traction question was made the dominant political issue in Chicago's mayoralty campaign, and had come to be regarded as about the only safe and certain means of transportation to the mayor's chair. It is true, the question was raised once too often and was not a controlling issue in the election last April; but the fact remains that the transportation question has proved to be a protfiable political issue in many of our larger cities on more than one occasion; and this is a factor to be reckoned with in considering the question of regulation.

True, the agitation, as a rule, is not so much over the rate which is fixed either by statute or by contract ordinance—almost universally at the flat rate of five cents—as over the question of service. This question vitally affects in a direct, personal way, almost the entire population of our cities, and daily involves the comfort and convenience of almost every citizen.

A car is delayed a few minutes by a breakdown on the tracks, or a blockade from some cause or other. This will probably inconvenience several persons. If the weather is bad, the discomfort may be extreme. Here is ground for complaint. When the blockade is lifted, the first cars must run by the next group of waiting passengers to adjust the headway—another ground of complaint.

Then there are the questions of heating and ventilating the cars, involving inherent difficulty and irreconcilable conflict. One passenger wants heat, regardless of ventilation; another wants ventilation regardless of heat—more complaints—calling for expert advice on the question of heating coils, thermostats, and for expert opinions on the merits of ventilating fans and systems of so-called natural ventilation.

The real problem is yet to come—the morning and evening rush hour service. Several hundred thousand people want to be carried into the downtown business district, and to their places of employment in the numerous industrial centers of this city in a two and one-half hour period in the morning. During a like period in the evening these several hundred thousand people, augmented by those

who have gathered in the downtown district during the day for shopping or other purposes, pour into the streets and want to be taken home immediately.

More than 250,000 people—a good sized army even in these days—are carried out of the downtown business district in this city during the evening rush hours by the surface and elevated lines. In addition to this, there is a similar rush hour problem for the great manufacturing and industrial centers of the city. During this period cars are operated to track capacity in the congested districts. Nevertheless, the cars are overcrowded—more inconvenience and discomfort, and more complaints. This same problem exists in every large city in this country.

For the non-rush hour service the usual standard sought to be reached is a seat per passenger during some reasonable average period. I shall pass over this question with the remark that however adequate our schedules may be, there are constantly interruptions and delays which unavoidably interfere with the regularity of the service, at times producing an overload; nor shall I dwell on that multitude of complaints due to the failure at times of trainmen to observe the service rules and regulations of the company. This involves a question of discipline, and a consideration of the human equation. With nine thousand conductors and motormen on the surface lines alone, handling more than 3,000,000 passengers daily, it is not strange that we have some complaints with reference to discourtesy, running by passengers, starting car too quickly, and other miscellaneous happenings.

Now, most of these complaints are perfectly natural. No one likes to wait for a car, much less in the rain or extremely cold weather. An actual wait of five to ten minutes very readily assumes in the mind of the impatient passenger, the proportion of from ten minutes to half an hour. No one likes to be passed up, or crowded, or jostled, or be obliged to stand up for several miles after a hard day's work, or to be treated discoutreously by employes of the company. For some of these complaints the company may be charged justly with responsibility—some can be remedied—some cannot be eliminated entirely. The rush hour problem has been with us for the last twenty-five years, and will be with us as long as the growth and development of this great city continue.

But enough has been said to make it apparent that the field for the regulation of transportation utilities in large cities is broad enough to cover in principle about every question that can be raised with reference to any utility, and presents an inviting prospect to the socio-political agitator or reformer, and a very difficult problem to the utility.

And with this promising field in sight, the opportunity for experimental regulation has not been overlooked: State utility commissions, city councils, boards of control have all taken a hand, and

in at least one instance, all have tried their experiments on the same utility at the same time in respect to the same matters.

MULTIPLE REGULATION OF STREET RAILWAYS IN CHICAGO.

The Chicago Surface Lines are regulated by the municipal authorities in several different ways.

In accordance with the terms of our ordinance, we have agreed "to comply with all reasonable regulations of the service * * * which may be prescribed from time to time by the City Council."

The City Council acts, in the first instance, through its Local Transportation Committee, a very active and persistent committee, aided and abetted by an equally active and persistent Transportation Supervisor. The City Council has not failed to avail itself of its rights of regulation. It has considered and is dealing with almost every possible service question.

But this is only the beginning of our regulation. After the City Council, we come under the jurisdiction of various municipal departments. There is the Commissioner of Health, who has to do with heating, ventilation and sanitation of cars; we are controlled to a considerable extent by the Commissioner of Public Works; and then we come to the Commissioner of Public Service, who deals with service complaints of all kinds and who has at all times a large force employed in checking up our service.

We are now only well under way in this matter of regulation. We have yet seventy Aldermen, representing the thirty-five wards of the city, to be accounted for, and each Alderman has the transportation interests of his own particular ward to look after in addition to the transportation needs of the city.

And working along the same line there are several scores of neighborhood or improvement associations who stand ready to join with all and singular the regulating agencies mentioned herein, in order to procure some local benefit or advantage.

We now come to the Board of Supervising Engineers, a board of experts created by the 1907 ordinances. On this board the city has a representative, the companies have the equivalent of a representative, and the third member is our honored chairman, Mr. Bion J. Arnold. This Board has a wide general supervision over the affairs of the company; it has control over construction, reconstruction, rehabilitation of track, roadway and equipment and all contracts therefor; passes upon our capital, renewal, and to some extent, upon our operating accounts, carefully checking all expenditures made by the company with a view of determining whether these expenditures come within the various provisions of the ordinances; and finally the board has the extremely important duty of passing upon the reasonableness of the service regulations prescribed from time to time by the City Council. This Board is constantly appealed to by the City Council or its Local Transportation Committee for advice and recommendations with reference to various matters.

I wish to say in this connection that one of the most valuable features of the 1907 ordinance is the provision providing for and establishing this Board. The ordinance provides that the Board shall be composed of engineers. The intention of the ordinance was to create a board of experts free from political influence. While the Companies have the right to appoint and remove their representative at any time, and the City has the same right as to its representative, who is appointed by the Mayor, subject to the approval of the City Council, the Chairman of the Board, who has the controlling vote, virtually holds office for life, or during good behavior, unless both the City and the Companies should agree to remove him.

This Board has supervised the expenditure, during the last eight years of over ninety millions of dollars of new capital expenditures made by the Companies, and no word or question during this entire period has ever been raised as to the integrity and good faith of the Board. And while this Board has passed as arbitrator upon a multitude of service regulations submitted by the City Council or its Local Transportation Committee, no appeal has ever been taken from the judgment of the Board.

But the end is not yet. Two years ago the state legislature passed an act creating a "State Public Utilities Commission." About a year ago this Commission assumed jurisdiction over the service of the street railways in Chicago. This resulted in an order by the Commission last September, covering pretty generally the whole field of service, involving a standard of service, the routing of cars, the class of equipment to be operated, car signs, etc. Among other things, the Commission ordered the Company to operate trailers, the use of which is prohibited by the terms of our ordinance. Regardless of the merits of the question this part of the order produced a somewhat novel situation in this, that if we were to comply with the order of the Commission with reference to the operation of trailers, we would subject ourselves to forfeiture of our street rights and franchises; and if, on the other hand, we failed to comply with the order of the Commission, the Company would be subjected to a maximum penalty of $2,000.00 a day for every day of such non-compliance, and the officers of the Company would be subject to a fine of not to exceed $1,000.00 or imprisonment not to exceed a year in the county jail, or both fine and imprisonment.

The City of Chicago in the course of vindicating what it deems its constitutional rights and jurisdiction in the premises, has recently filed a bill seeking not only to enjoin the State Public Utilities Commission from attempting to enforce this order, but also to enjoin the companies from attempting to comply with this order. And so the matter stands, awaiting the decision of the Court.

This multiple regulation has resulted in a great waste of time, not only on the part of public officials, but on the part of the officers and employes of the Company. The saving feature has been the fact that most of the questions arising with reference to regula-

tion were finally presented to, or will be presented to, the Board of Supervising Engineers for decision.

There have been times when the City officials were not inclined to avail themselves of the services of this Board. I believe, however, that the tendency at the present time is in the other dirction, and the policy as to those matters on which the Company and the City officials cannot agree, is to submit the questions to and abide by the judgment of the Board of Supervising Engineers. This arrangement is based upon a sound principle and a full recognition of the advisability and necessity of having these questions determined by competent experts.

THE PRESENT SITUATION WITH REFERENCE TO REGULATION OF THE STREET RAILWAYS.

I shall not attempt to trace the history of the beginning and development of the regulation of utilities. I shall assume that the prevalent popular opinion is in favor of the necessity of some system of regulation.

It is a legal concept that these utility companies have devoted their properties to a public use—that they are engaged in rendering a public service and are, therefore, subject to be controlled through some governmental agency representing the public.

Hence we have state public utility commissions and various regulating bodies, such as city councils, boards of trustees, committees and boards created by ordinance.

The American public is insisting year after year upon higher and higher standards of service. The street railway service which the public would have accepted ten years ago, would not be tolerated for a moment today. In fact, all of the energy, resources and inventive ability of those who have developed electric railway service, have been directed towards providing an improved service. This improvement has taken the course of furnishing the most modern and efficient power plants, the best possible track, roadway and overhead equipment, the best lighted, the best heated, and the most comfortable cars which the development of the industry so far has produced.

If one were to pass in review the improvement in equipment, beginning with the horse car of less than twenty-five years ago, unheated, poorly lighted, and with a speed of upwards of three miles an hour, and ending with the latest type of electric car, electrically heated, lighted and operated, equipped with air brakes, and having a speed on interurban lines equal to that of steam railroads, one will have a picture of the progress which needs no comment. There can be no question that the standards of service which are accepted as the best standards obtainable today will be superseded by better standards of service as fast as the progress of the industry and the increase of facilities permit.

But there is another side to this question. While all these im-

provements have taken place, the fare upon which the Companies have been compelled to supply and develop this service has remained stationary. It was five cents in the City of Chicago when the first horse car in 1859 was operated on State street from Randolph street to 12th street—a distance of a little over one mile. It is five cents today for a continuous ride, within the city limits, from 138th street on the south to Norwood Park on the northwest—a distance of 30.5 miles.

This situation has not, as a rule, been given fair consideration by those who have had to do with the regulation of these utilities. If there have been instances in the past of unfair treatment of the public by the public utility companies, such a policy is the exception and not the rule today; and there can be no question that the unfairness and abuses of which some of these utilities may have been guilty in the past have been more than paralleled by the treatment they have received, and are receiving at the hands of their rgulators.

Year after year these companies are subject to wholly unnecessary interference with the operation of their properties by over-regulation, with all of the expense and embarrassment connected therewith, and finally, with a constantly increasing pressure towards decreasing the return upon the investment already made.

Now it is perfectly evident that while these regulators may control, to a large extent, the fate of the capital already invested, there is one element over which they have no control, and that is the prospective investor whose co-operation is absolutely necessary to the development of this utility. Not only this, but the investor of tomorrow is going to determine his course of action by reference to the treatment accorded the investor of yesterday.

Let us turn for a moment to glance at the magnitude of interests represented in electric railways alone, and the trend of development. This industry in the United States today represents a total capitalization of approximately $5,000,000,000.00; it employs approximately 300,000 men; it disburses in salaries and wages each year more than $225,000,000. In 1912 the business had a gross income of $585,930,517.00, and expended in carrying on the business, in what is generally referred to as "operating expenses" the sum of $332,896,356.00, and during the same year, 41,064 miles of track were operated. These figures will indicate something of the magnitude of this particular utility.

Notwithstanding the amazing increase in this industry in former years, and the enormous capital involved, the last few years have shown a startling change with reference to the development of this industry.

During the five year period from 1902 to 1907, the capital invested in electric railways increased 63.5%, while during the five year period from 1907 to 1912, the increase in capital was only 24.7%, and the figures so far available, covering the period from 1912 to date show a still further decrease in the amount of capital seeking investment in this business.

During the five year period from 1902 to 1907, the gross income of street railway properties in the United States increased 71.6%. During the five year period from 1907 to 1912, the increase in gross receipts was only about one-half of this amount, or 36.3%.

The capital increase from 1902 to 1907 was $1,466,489,997.00, or at the rate of $5,640,346.00 per week. The capital increase from 1907 to 1912 fell to $933,796,045.00 or an average of $3,591,523.00 per week—a decrease of over 36%.

We know that the first period was one of unusual growth—the industry was getting its stride—yet the heavy decrease during the last seven or eight years challenges attention and demands an explanation.

We are all familiar with the fact that while the rate of fare of the street railway company has remained stationary, almost every factor in the cost of producing the service has increased. In the United States wages of street railway trainmen increased during the period of ten years from 1902 to 1912, inclusive, approximately 20% and the actual increase in average hourly wage on the Surface Lines from 1902 to the present time has been approximately 44%. Furthermore, the cost of most items of material and supplies, used in construction and operation, has increased.

The length of haul in Chicago has increased from 13.3 miles in 1907 to 30.5 miles in 1915. The average fare per passenger, taking into account the issuance of transfers for the year ending January 31, 1908, was 3.02c per passenger. By the constant increase in transfer privileges, this fare has dropped during the succeeding seven years to 2.80c per passenger for the year ending January 31, 1915.

The abnormal conditions existing during the past eighteen months are, it is hoped, more or less temporary, and are not, perhaps, controlling in judging the situation. The fact remains, however, that it has only been by the most rigid economy that the companies have been able to make the stationary fare meet the increasing operating expenses and higher standards of service.

It is also apparent to any one familiar with operating problems that many of these economies have already been carried as far as they can legitimately go; that the "irreducible minimum" has about been reached; and that further efforts to reduce operating ratios by decreasing the expenses for maintenance and upkeep of power plants, track and roadway and equipment, afford no real solution of this problem, and only delay the final reckoning.

I mention these facts in order to call your attention to the actual situation now existing with reference to these utilities, and to the fact that the future of these utilities has become a question of vital concern; and that the situation is one which sooner or later must be given recognition by the various regulatory bodies with which we have to deal.

PURPOSE OF THESE COMMISSIONS.

We now have state public service commissions having jurisdiction over electric railway lines in twenty-six states, exclusive of the District of Columbia or the Philippine Islands. We have state public service commissions having jurisdiction over interurban, but not urban, railway lines, in five additional states. We have state public service commissions having no jurisdiction over electric lines, but having jurisdiction over steam roads in fourteen other states, leaving but three states, namely: Delaware, Utah and Wyoming, in which there is not a state public service commission of some kind.

The several acts creating these commissions have vested in them certain general and specific powers, and in the essentials all of the acts of the modern type are substantially alike. Practically each one of these acts deals with the two vital questions of service and rates. The real work of regulation lies in dealing with these two factors.

An examination of the public utility commission acts now in force shows the following:

In thirteen of the states the act requires the charge for the service to be "just and reasonable"; in five states the requirement is "reasonable and just"; in two, the requirement is "reasonable"; in one, the requirement is "just and fair"; in one, the requirement is "must be reasonable"; in another, the requirement is "just and reasonable," with the further qualification that "no street or interurban railroad to receive more than five cents for one continuous ride within the city limits, except when shown that the same is justified"; and another makes no provision as to whether the charge shall be just and reasonable, but says: "No street railway to charge more than five cents for one continuous ride within the limits of any city or town"; the others make no specific provision on this subject.

On the question of service, the general provision is that the service shall be "safe and adequate," "reasonably adequate," "safe, adequate and sufficient," "just, reasonable, safe and adequate," "reasonable, efficient and sufficient," etc.

The theory of these acts is that a definite relation exists between the service furnished and the charge or price for such service. The theory is economically correct: the unfortunate thing is that it is not applied in practice. The steam railroads complain that the Interstate Commerce Act authorizes the commission to fix maximum rates, but gives it no power to fix minimum rates; that the law provides that the rate shall be reasonable, but gives the commission no power to make the rates reasonable in case they are already unreasonably low.

Electric railway companies say that the rate is fixed usually by ordinance grant—almost universally five cents—while on the other hand the cost of service is constantly increasing; that higher standards of service are demanded, and consequently still higher operating expenses result; and that the companies have a moral and legal

right to insist that these matters must be considered in connection with regulation.

The difficulty presented by this situation is that the two factors are not equally considered. There is a definite and a necessary relation between the service standard, or quality of service, and the price which is being paid by the public for the service. This situation results too often in a disregard of the principle that no service can continuously be furnished at less than cost, and that a street railway, or any other utility, in that regard, stands in exactly the same situation as any other business.

Now, presumably, the creation of the public utility commission in one form or another in practically every state in the Union was with a definite purpose in view. An examination of the conditions leading up to the creation of these various utility commissions and regulatory bodies, and an examination of the acts and ordinances themselves indicate that the apparent purpose of these acts was to procure good service at reasonable rates and to prevent discrimination. This is generally expressed in these acts by saying that the service shall be "adequate, just and reasonable," and that the charge therefor shall be "just and reasonable."

FACTORS INVOLVED IN GOOD SERVICE.

The people want good service from these utilities. They have elected or appointed these various councils, commissions and boards and vested them with certain powers, apparently for the purpose of getting good service.

Before we consider how to get good service by the general panacea of regulation, it will be necessary to have a clear understanding as to what factors are involved where the avowed purpose of regulation is to secure good service.

It is not my purpose, in this connection, to discuss standards of service or methods of measuring service, but I do wish to consider and, if possible, get a clear idea as to what is involved in procuring good service through the medium of regulation.

The difficulties that arise and the mistakes now being made in attempting to regulate the service are due either to a failure to understand what is involved in regulation or an unwillingness to treat the subject fairly.

There are three controlling factors to be considered in any regulation with respect to service:

(1) *Continuity of Service.* The first factor in good service is continuity. Provision must be made, not only for good service today, but for good service tomorrow and thereafter so long as the service is needed.

(2) *Extension of the Service.* The second factor in good service is the extension of the service. Provision must be made not only for the continuance of the service in the territory or community where service is needed today, but also for the extension of

the service to keep pace with the growth and extension of the community.

(3) *Improvement of the Service.* The third factor in good service is improvement. Provision must be made for constant improvement so as to keep pace with the progress and development of the industry.

Good service means good service today and tomorrow and thereafter, not only as measured by the present demands and conditions, but that which will keep pace with continuity, development and growth. The service demanded a few years hence may make the service afforded today, however good, seem poor indeed.

The difficulties which have arisen in attempting to regulate these utilities are largely due, in my judgment, to the failure on the part of the public, and its representatives, to realize that these three elements are necessarily involved in regulation. The public does not understand, and has not been shown, that no satisfactory regulation or permanent solution can be had otherwise.

The fact that the public is not well informed on this subject is partly due to the failure on the part of the utility companies to place these facts fairly and clearly before the public. For that we may assume our share of the blame.

There is nothing new in this, it seems commonplace—perhaps it is—but it is fundamental. We can no more discard fundamental principles in this matter of regulation than a builder can dispense with the foundations for his superstructure.

If you think it is not fundamental, take the history of any of the bitter disputes concerning regulation that have been waged before commissions, in the courts, in the public forum and in the public press, and see if in the last analysis the disputes did not directly or indirectly involve these factors.

The main difficulty on both sides—on the side of the companies and on the side of the public and its honorable commissioners, councilmen and other representatives—has been that they have had too narrow a view of the practical elements involved in this problem of regulation. There is vastly more involved than merely fixing some more or less arbitrary standard of service for today.

The trouble is that the question has been viewed from the standpoint of today rather than from the standpoint of today and tomorrow. The difficulty has been that neither the public nor its representatives has accorded the proper weight to the importance of a guaranty for the continuity of the service and adequate provision for future extension and improvement.

A mere order directing compliance with a certain standard of service does not solve the question of regulation, nor end the responsibility of the commission or regulating body. Adequate provision for the maintenance of the service in the future must be made. The offer of a utility company to supply service pre-supposes the existence and operation of a suitable plant and equipment, and this

involves the consideration of adequate reserves for maintenance and renewals. Unless these reserves are maintained, the service is bound to deteriorate. Efficient and reasonable regulation, therefore, requires that due allowance for these elements be made when any regulation or adjustment of service is being considered.

Granting that it is necessary to provide for the continuity of the service, why should the extension of the service into new territory in the more or less distant future be considered as a factor in regulation? A little consideration will answer this question:

Our population is steadily increasing; our cities are growing and expanding. In Chicago, for instance, it is literally true that the cornfield of last year is the site of a new subdivision this year. This new subdivision offers the strongest inducements to the people, in the more congested districts, to move out, but the people as a rule are not anxious to do pioneering. Before they will move out they want to be assured of the advantages of the service offered by these utilities. Owing to the limited demand for service in the new territory, the service in nearly every case is, for a considerable time, rendered at an actual loss. The extension of service into new territory of this character can only be warranted by faith in the future.

Millions and millions of dollars are raised and expended by these utility companies in extending service into new territory, which for a considerable time will not, and may never, even pay operating expenses, much less a return upon the investment. In many instances these extensions are not voluntary but compulsory.

These companies as a rule have no means of raising money except their credit. This means that the ability of these utilities to extend their service to keep pace with the development of these great communities must depend absolutely upon their ability to go into the market and borrow money in competition with every other industry seeking new capital.

Unless these utilities are able to offer as good terms and as good security as other enterprises seeking investment, they cannot possibly procure the capital needed. And in the last analysis, the intelligent regulation of these utilities imperatively demands, as a first and foremost consideration, public recognition of the necessity of having the credit of these companies maintained at the highest possible standard.

The public derives no benefit from a utility suffering from a case of "arrested development." On the other hand the public wants to be assured that the service it demands will be extended to keep pace with the development of the community.

Nor is it sufficient to consider only the continuity and extension of service. The public demands the benefit of every invention and every improvement in the industry which will benefit the service. The candle, the kerosene lamp, the gas light, the electric light; the horse car, the cable car, the electric car—these words alone suffi-

ciently indicate the development and progress made in the service furnished by these different utilities.

These mile stones of progress mean that plant and equipment costing millions of dollars have time after time become obsolete and been replaced by new plant and equipment, in order to keep pace with progress. We all recall the situation when a few years ago the electric car superseded the cable car. Cable plants and equipment costing millions of dollars were scrapped and replaced by electric plants and equipment costing many millions more.

All this has added to the financial burdens of the industry but has resulted in economies and improvements which make the present standards of service possible. Will any one say that this has not operated to the benefit of the public? Will any one say that new plant and equipment could have been acquired had it not been for faith in the future and a confidence that the capital invested in the old plant and in the new would be protected?

What has happened may happen again. Tomorrow some inventor may say: "Scrap your present plant and utilize my invention, which has revolutionized the industry." It may be of vital interest to the public that this be done. But it cannot be accomplished unless the credit of these companies is kept at the highest mark, and all doubts as to the security of the investments made and to be made are dispelled.

The credit of these companies can be most seriously impaired by unwise regulation, and with the credit impaired, in the long run, the public will be the chief sufferer. The public again has a very vital interest in having these factors considered and protected in any regulation which may be contemplated.

The power to regulate carries with it the power to destroy. No fair-minded person, I take it, claims that the public utility commissions were created to destroy these utilities; and no one, I take it, denies that it is the duty of these commissions, in connection with and as an adjunct to their regulation of these utilities, to provide for their preservation and development.

BASIS OF SOUND REGULATION.

By sound regulation I mean regulation that will stand the test of time. I do not mean mere political experimenting, which promises something for the moment and ultimately ends in disaster.

There is no magic in this matter of regulation, nor are commissions or other regulators able to obtain service at less than cost any more than a manufacturer is able to sell his product at less than cost and continue in business.

The utilities are business institutions and as such are governed by business principles. Irrespective of any question of regulation, the success of these companies depends upon the adherence of the management to sound business principles. It is obvious that if regulation is to succeed ultimately, it must be by the application of sound business principles.

Without attempting to enumerate all of the elements which should be considered in sound regulation, I submit these:

(1) *Regulation presumes just, reasonable and adequate service requirements, based upon just and reasonable compensation.*

These two factors are related so intimately that neither can be considered separate from the other.

Legislative fiat or administrative orders cannot bring about public service for less than cost. The same inexorable laws are met in this field as in all other business enterprises.

In the regulation of street railways where the compensation is practically fixed, a problem of constantly increasing difficulty is presented. These companies are now being called upon to face higher and, in some instances, drastic service requirements together with a constant increase in operating expenses.

Where this situation exists and economy and efficiency have reached their reasonable limit, and it is proposed, through the medium of regulation, to still further increase the cost of the service, there are only two sources from which the increased cost can be taken, namely: maintenance and renewal funds and the income to the investor.

If the increase is taken from the first source, it means a deteriorated service with a heavy bill to foot in the end. If taken from the second source, to the extent of impairing a fair return to the investor, it means the inability of the company to extend its service or provide for its improvement.

This problem of fair return to the investor, of course, involves the question of valuation, where a valuation of the property has not already been made. This discussion does not involve methods or principles of valuation. One thing, however, is certain and that is the valuators are dealing with the rights of a third party—the investor—and upon their treatment of him, with reference to money already invested, will depend his attitude as to future investments and upon his attitude must depend the future of the utility.

Where a new contract or a new arrangement between a street railway company and a municipality is being considered, another situation presents itself. Assuming that a fair valuation has been fixed and a fair rate of return has been agreed upon; and assuming that a high standard of service is desired; the first essential is to provide for using the entire fare for transportation purposes.

By this is meant the necessity for relieving street railway companies from those burdens which are not a legitimate part of the cost of transportation—for example: the obligations to pave, maintain the paving in, and clean that part of the street occupied by the company's tracks.

Electric cars do not wear out the pavement and do not scatter dirt and refuse upon the street. All this is a relic of horse-car days, and that part of the fare which is used for these purposes is not being used for transportation purposes.

Surely the street railway company, which by the extension of its lines and the expenditure of its money has in many instances doubled and even trebled the value of property to the abutting property owner, has done enough for the property owner without being called upon to help him pave and clean the street.

Nor are these items unimportant. During the eight-year period ended January 31, 1915, the surface lines have expended approximately the following amounts for these purposes:

Paving right of way	$ 8,397,796.46
Maintaining paving	1,550,204.39
Cleaning right of way	2,905,391.53
Total	$12,853,392.38

The same thing is true with reference to the millions of dollars which street railway companies are required to expend for the removal and replacement of their tracks to make way for the construction of sewers and other underground improvements being installed by the city. This expense, in most instances, falls upon the street railway company and constitutes an important item in the cost of service. The property of the street railway company, when laid in the street, is entitled to the same protection as any other property. If some other utility is being constructed in the street and in so doing it is necessary to destroy a part of the property of the street railway company, the value of the property so destroyed should be considered as a part of the cost of such other utility, and the street railway company reimbursed to the full amount of its damage and expense.

The patron who pays a nickel for a street car ride is entitled to a nickel's worth of transportation, and in large cities where the cost of rendering the service is constantly increasing, it will be necessary, when the contract relations of the city and the company are being readjusted, to provide that the entire fare shall, if necessary, be used for transportation purposes.

(2) *Regulation must not be so directed as to destroy the incentive to economy and efficiency.*

Utility companies have just cause to complain about unwise and harmful regulation. A standard of service is prescribed, the utility sets about to meet it. When through additional economies, the company has adjusted itself to the new conditions, and appears able to survive, still further burdens are promptly imposed until the companies are beginning to say: Of what use is it to attempt to meet these new conditions, inasmuch as in the end any margin of safety, which we may secure by the most drastic economies and the highest standard of efficiency, will be absorbed by some new burden.

A utility company is no different from any other corporation. It responds to the same incentives. Its welfare and sound public policy both demand an incentive to further economies and greater

efficiency. This incentive must be found in the reasonable hope of some reward for such efforts.

(3) *A reasonable standard of service having been prescribed, the method and detail of providing that service should be left to the utility.*

The reports of the utility commissions show many controversies arising out of an attempt on the part of the commissions to regulate the details of operation.

It is to be presumed that in the operation and management of their property, the owners of the utility will themselves bring to their aid the best talent which they are able to procure for the efficient operation of their property.

It is quite obvious that such details are better dealt with by the operators and owners of the property than by these commissions or regulating bodies who could not possibly, under the present system and tenure of office, be expected to have the experience or familiarity necessary to enable them to deal satisfactorily with such questions.

(4) *Unnecessary interference with operation is bad and tends to increase the cost of the service and to increase the cost to the public of maintaining the regulation.*

The various utility acts confer extremely broad powers upon these commissions, and these commissions, like all other bodies, have a strong tendency to exercise the powers conferred upon them, regardless of the necessity or the advisability of doing so.

The result has been an increasing tendency to interfere with the details of the management of these utilities. Particularly has this been the case with the steam roads and electric railways. No good purpose has been, or possibly can be, subserved by this course.

About all that has been effected in this way has been to cause considerable irritation on the part of the utility company, particularly owing to loss of time, extra expense and interference with the operation of the property; and also to incur a large amount of additional expense for clerical and other work on the part of the commission, which in the end the taxpayer has to meet.

The fact is that neither the taxpayer nor the utility company is getting value received for the money thus expended.

(5) *The right to regulate these utilities is neither municipal nor state ownership.*

Our regulators have a tendency to assume many of the prerogatives of ownership, but at the same time to avoid carefully any responsibility for the outcome of the enterprise.

In all this the regulators are fixing the price, or prescribing the quality of service, or both, but they have assumed no responsibility for furnishing necessary capital, or working out the problems of furnishing the service for the price fixed. The tendency is to give undue consideration to one side of the proposition—the popular side.

There can be no question that all this is a departure from sound

business principles and must in the end work to the injury of the public by resulting in a deteriorated service and inability to extend and improve the service.

The important points that cannot be too often stressed are: That regulation is not management; that no property is of any real value without the beneficial use thereof; and that ownership and management must abide together.

IN CONCLUSION.

The situation which these utilities face throughout the country can be pictured forcibly by contrasting the earlier policy, particularly in Illinois, with the policy of today.

In former days, as one writer puts it:*

> "In order to afford effective stimulus for inventive genius and business initiative it was necessary to provide a free field for private enterprise unhampered by legislative restriction. The technique of utility operation in which so high a degree of efficiency has now been attained had yet to be worked out; and the permanent necessity and financial practicability of the utility service which have now been recognized beyond recall, had yet to be established."

In 1848 the people of the State of Illinois in adopting their constitution provided:

> "The General Assembly shall encourage internal improvements by passing liberal general laws of incorporation for that purpose." (Sec. 6, Article X, Constitution 1848.)

Regulation through administrative agencies, of the type of the modern commissions, is a recent development. The numerous acts creating these commissions have been framed upon the models of the Wisconsin and New York acts of 1907.

From that date regulation of public utilities has proceeded a pace.

At the 1911 session of the Illinois Legislature, the agitation for this kind of experimental legislation against public service corporations resulted in the introduction of numerous bills, of which it was said that if they

> "were crystallized in the form of law there would not be a public utility concern in the State of Illinois able to continue in business."

In 1913 the Illinois Legislature passed an act entitled: "An act to provide for the regulation of Public Utilities."

This act is made up largely of provisions taken from the Wisconsin, California, Massachusetts and New Jersey laws. This act extends the provisions of those laws, in many respects, in a most radical manner, and gives ample evidence of having been written

*Commission Regulation of Public Utilities—A Survey of Legislation, Vol. 53, Annals American Political and Social Science, No. 142, p. 1.

largely from an academic and theoretical standpoint, and with a pronounced bias against public service corporations.

Taken literally, this act may be summed up in the following language:

> "Now that you have under the authority and encouragement of law established and developed the internal improvements which we so much desired and needed we will take from you the power of management and control of your properties, and while leaving you with the burdens and responsibilities of technical ownership, we will create a commission which, without any responsibility for your investment, will determine what new, additional or improved facilities and equipment you shall furnish; which will fix your charges for service; prescribe the method of keeping your accounts; control your contracts; prohibit you from issuing or determine when and in what amounts and upon what terms you may issue any stocks, bonds, notes or other evidences of indebtedness, and how you shall use the proceeds thereof; compel you to enter into operating contracts with other corporations and on such terms as it may designate; require you to permit other corporations to use your property; call upon you at any time for detailed reports and inventories; subject you to inquisition at any and all times; prescribe rules, regulations, standards and practices for the conduct of your business; summon you before it and require you to defend against every complaint that individual prejudice, cupidity or animosity can conjure up; and enforce against you enormous penalties, and against your officers and agents fines and imprisonment for failure to obey any of its orders, rules or regulations."

To give full effect to the strict letter of the act would amount to the state, through its commission, taking over the detailed management and control of the properties of every public utility corporation therein, leaving to the corporations the bare legal title to their properties and making them mere agencies for purposes of operation.

Nevertheless the present state of public opinion is such as to put the public utilities in the position of defensive acquiescence, of relying in the first instance upon the good sense, spirit of fairness and recognition of the constitutional guaranties on the part of the commission, and appealing to the courts only as a last resort.

In the meantime, the public utilities are facing a real crisis. Their hope lies in a better understanding by the people of the problem from their own as well as from the utilities' standpoint. This involves an appreciation of the facts that there are mutual and reciprocal rights and duties on both sides, that govermental regulation and control of public utility enterprises is still a social and political experiment and not a specific panacea, and that utility regulation is not sustainable morally, legally or economically, as an arbitrary

exercise of governmental power, but only as a method of control which consists in defining and enforcing the reciprocal rights and obligations of the utilities and the public based upon principals of justice and proceeding along the lines of fair and honest endeavor to harmonize the general welfare of the public with the property interests of the owners of the utilities.

Mr. Justice Moddy states the situation clearly in *Knoxville v. Water Company, 212 U. S. 18:*

> "Regulation of public service corporations, which perform their duties under conditions of necessary monopoly will occur with greater and greater frequency as time goes on. It is a delicate and dangerous function, and ought to be exercised with a keen sense of justice on the part of the regulating body, met by a frank disclosure on the part of the company to be regulated. The courts ought not to bear the whole burden of saving property from confiscation, though they will not be found wanting where the proof is clear. The legislatures and subordinate bodies, to whom the legislative power has been delegated, ought to do their part. Our social system rests largely upon the sanctity of private property, and that State or community which seeks to invade it will soon discover the error in the disaster which follows. The slight gain to the consumer, which he would obtain from a reduction in the rates charged by public service corporations, is as nothing compared with his share in the ruin which would be brought about by denying to private property its just reward, thus unsettling values and destroying confidence. On the other hand, the companies to be regulated will find it to their lasting interest to furnish freely the information upon which a just regulation can be based."

Along these lines the problem must be worked out. In the end the American spirit of fair play is sure to assert itself; and with greater publicity as to their affairs, and a continuance of their policy to serve and please the public on the part of the corporations, and a better understanding by the people of their real interests, the present popular feeling of antipathy towards public utilities will be supplanted by one of confidence, and regulation of the present-day radical and destructive sort will give way to constructive and helpful co-operation.

DISCUSSION.

Bion J. Arnold, M. W. S. E.: Mr. Chairman and Gentlemen: I had no idea when my friend Mr. Rice here brought me up to the speakers' table that I would have to make the first speech.

Now that I am on my feet I do not know what to say because unfortunately I was delayed in getting here. I expected to be here in time to hear the whole paper Mr. Busby has presented to you bcause I felt certain he would present something of interest and importance. I got in just about fifteen minutes ago and only got

the last part of it, so I do not know what he said in the main part of the paper.

I, however, know something about the troubles of utility corporations. I also know a little something about the regulating side of the utility subject. I do not know exactly what utility corporations that I have had to do with the regulation of think of me, but sometimes, although not always, I think pretty well of them and especially do I think better of them after I find out their troubles.

I presume that Mr. Busby pointed out in the first part of his paper the situation that the utility companies find themselves in, presumably in Chicago, and I know in other places, and said something about—at any rate, he did in the last part of his paper—about what he thought ought to be done to extricate them from their present situation.

A great many of the companies—I would not say a great many but a number of the utility corporations—have passed through the reformation, I might say, and made settlements with the municipalities in which they operate. I am speaking now of electric railways, electric lighting companies, gas companies, and so forth. You know we here in Chicago some eight years ago passed what we called settlement ordinances and we have been operating under them since. They also passed a settlement ordinance in the city of Cleveland; have been operating under that for about seven years, I think. They have recently passed a settlement ordinance in Kansas City. That has not yet become a law except to this extent: It has passed the city council, has received the mayor's approval, has been voted upon by the people, passed by a large majority, and is now before the state public utilites commission for a certificate of necessity and convenience. Whether the company will get it or not I do not know, but I presume it will. Then they have passed the Boston gas case ordinance and some other lighting and gas utility ordinances which I will not weary you with.

But take these three fundamental ordinances that I speak of that refer particularly to street railways in our large cities. I do not know whether I am talking to the paper or not, but I can talk perhaps to some part of the subject. In our case in this city we happened to have to tackle the problem first and we wrote ordinances. The attorneys for the city and the attorneys for the companies agreed upon an ordinance. The engineers for both sides also had something to do with it and the result was this 1907 ordinance. Now that is a very good ordinance, although it has some weak points. In these other ordinances that I speak of an attempt was made to correct some of these weaknesses. The Cleveland ordinance, instead of allowing the companies a fixed return, say of five per cent as we do in Chicago and then giving them a chance to make something in addition as we do here, fixed the rate to the companies there at six per cent and no more. We have operated under the Chicago ordinances for about eight years and the companies have

made between six and a half and seven per cent, sometimes over seven per cent, close to eight; but the average, I think, is between six and a half and six and three-quarters per cent upon the purchase price as defined in the ordinance. In other words, while they practically are not guaranteed five per cent, in effect it means a guaranty, owing to the character of the business, although if they do not make it they do not get it. But they are reasonably sure of making the five per cent. Then all over and above that is divided between the city and the company and under that arrangement they have made between six and a half and six and three-quarters to a little over seven. In Cleveland they limt them to six per cent and no more.

In Kansas City—I was consulted in that case and in fact had considerable to do with it—we endeavored to rectify some of the weaknesses of this Chicago ordinance to the extent that the company is allowed six per cent and no more for a certain period of time. During that period of time all the surplus over and above six per cent upon the agreed capitalization, which in that case was thirty million dollars, all of the net profits over and above the six per cent on the investment goes into the company amortization fund to retire, amortize, or hand back to the investors, that part of the property which is known in technical valuation work as intangible value. In other words, it is money that has been spent for obsolete property, such as old horse cars, old cable cars, small electric cars, old rails and so forth; also any money that may have been spent by the companies in reorganizing or in attorneys' fees for reorganizing the company or other expenses of that character that had to be spent in order to get the properties up into the situation we found them when we valued them. There are a number of other elements that went into the development of the property, which I call development expense, and all of them intangibles. All profits of this company over and above six per cent go toward the elmination of those intangibles until they are completely eliminated, until the visible or tangible property is equal to the value as capitalized. After that time the company and the city share in the profits as in Chicago.

It seems to me that is a pretty fair plan, because they did what we should have done here. In other words, it provides a means of eliminating or handing back to the man who put his money into the property so much of the money that he has put into it as is not longer needed in the property. That gives him a return upon it just as long as he has that money in. In some localities they attempt to amortize such part of the capitalization by legislation, take it away from the companies, which is, of course, unjust, provided the companies have put the money in fairly and honestly.

That is the thing we have to look out for in these settlement ordinances or should look out for, at any rate. The public is apt to claim that the corporation is all wrong. Sometimes it is wrong but it is not always wrong. The public claims it is all wrong, corrupt, and therefore has no moral rights. Therefore let us take it

by the throat and take away from it all these tangible values and make the rate upon the present or depreciation value of the property. That might be just in some instances if the corporation had been badly managed. When I say badly managed I mean improperly managed to the extent of charging a higher rate and declaring excessive dividends and not putting the necessary money back into the property to keep the property up. But where the property has been properly managed and kept up that is an absolutely unjust thing for the public to do, although it has tried in many instances to do it.

So I say the settlement should provide a means for honorably and honestly retiring these intangible values and that is what we are doing at Kansas City.

I think that we should go one step farther in future settlements. We should not only retire this intangible value, whatever it is, but we should also establish a standard of service, have some proper body to see that that service is maintained. Then, as Mr. Busby said, leave it to the company to create the means for providing that service, but have somebody authorized to say what the service is and what it ought to be. Then after that service is given according to the agreed standard, let there be an agreed interest return to the company upon this certain service standard; that is, a certain return upon the money invested in the property, assuming, of course, that the capitalization is agreed upon to start with and means are provided for adding to the capital in the future the same as we have in Chicago and these other places I have mentioned. The company should have a certain return, say six per cent, if you choose, or seven per cent or whatever you agree upon, upon the then agreed capitalization. Then if they better the service above that standard thy should be allowed an increased return upon the investment. That is similar to the Boston gas company's settlement. In other words, do not take completely from the companies the incentive to manage their properties better, to give a better service, like Cleveland does; but give them a fixed return upon a certain service standard and then give them a better return if they give a better service to the public, and put all of the nickel into service instead of putting it into a fund somewhere to create contention over.

THE ADVANTAGE OF A COMBINED USE OF TABLES AND FORMULAS IN THE COMPUTATION OF BRIDGE STRESSES

By R. P. V. Marquardsen, Assoc. W. S. E.

INTRODUCTORY REMARKS.

Text-books on bridge design generally contain some sort of moment table which will facilitate the calculation of live-load stresses in bridge members; but few, if any, give formulas to be employed in connection with these moment tables which would further lessen the labor of the computations.

While it must be admitted that any kind of labor-saving device is better than none, it seems strange that a very elaborate table with several columns of moments should be introduced, when a less complicated one, if used in conjunction with proper formulas, would reduce the work as well as the chance for error by about one-half.

The aim of the following pages is to present to the reader

(1) a simple form of moment table whose construction is easy and practically self-checking;

(2) formulas for its use, systematically arranged, and

(3) concrete examples with their detailed solutions which will tend to demonstrate the advantage of a combined use of formulas and moment tables in calculating bridge stresses.

DEFINITIONS.

By the term *base loading* will be understood the loading shown diagrammatically on the accompanying moment table, or the loading on which the moment table used is based.

By *system of loading* will be meant that portion of the base loading which is on the span, or spans, under consideration. Any concentrated loads which may be at the points of support will be regarded as being on the span, or spans.

The base loading will be supposed to be moving from right to left. When the first concentrated load of the base loading is at, or to the right of, a given point, it will be understood that no portion of the base loading has passed that point. Formulas pertaining to problems where a portion of the base loading has passed left-hand support of span under consideration will be referred to as *general case formulas,* and formulas pertaining to problems where no portion of the base loading has passed that point (or some other particular point to be indicated in each case) will be termed *special case formulas.*

The formulas developed in this article are general case formulas, and may, of course, be employed in solving any problem, whether or not certain special conditions exist; but as the special case

formulas usually are easier to apply, it will perhaps always be found expedient to note the special conditions existing in the problem at hand, and select the proper special case formula as given in connection with Figures 1 to 8.

MOMENT TABLE.

The accompanying form of moment table is an old one and may be found (slightly modified) in different books on the subject. It is of the very simplest kind and is practically self-explanatory.

In its fourth column is shown the base loading, or the given live load for which it is desired to compute the stresses in a certain bridge.

The first column gives, as its heading indicates, the distances in feet from the first concentrated load of the base loading.

Any number in the third column which is headed "Sum of Loads in Lbs.," represents the total weight in pounds of that portion of the base loading which is located between the first concentrated load and the line below the number considered, the weight of concentrated load No. 1 and that of any other concentrated load which may be on the line in question being included.

The numbers in the second column whose heading is "Moments in Foot-Lbs." give the sum of the moments of all the loads represented by the weight-number found in the third column on the same line as the moment-number considered, the center of moments being at a distance to the right of the first concentrated load of the base loading equal to the number of feet given in the first column on the same line as the moment-number in question.

The moment table presented herewith has only been calculated for a distance of 200 feet from concentrated load No. 1; but, of course, might be extended to any desired length; and such an extension would probably prove advantageous if spans of greater length than 200 feet were to be considered, especially as the work involved would be very small.

The construction of a similar moment table for any other base loading may be effected quite readily by pure addition, as follows:

Having divided the moment table into its four columns, and having made it of the desired length by drawing the requisite number of lines, write the distance-numbers in the first column, and construct the diagram of loading in the fourth, giving the weight of each concentrated load and the weight per lineal foot of the uniform load.

The weight-numbers representing the sums of the loads can now be written in the third column, the necessary addition being performed mentally.

As may be observed from the accompanying moment table, and as a little reasoning will make clear, any moment-number in the second column (as long as uniform loading is not involved) is equal

to the sum of the moment-number on the preceding line and the weight-number found on this same (preceding) line. As soon as uniform loading is reached, any moment-number in the second column is equal to the moment-number on the preceding line plus the weight-number found on this same (preceding) line plus one-half the weight per lineal foot of the uniform loading.

NOTATION.

The use of composite characters in equations is, as a general rule, objectionable; but this is chiefly because capitals as well as lower-case letters have been used indiscriminately to represent values and as modifiers. If, however, as will here be the case, capitals are employed solely to represent values, and lower-case letters are used only to restrict these values, then there should be no ground for confusion on that account.

In the formulas to be derived presently the following symbols will be used:

B followed by one lower-case letter = bending moment in foot-lbs. due to the system of loading at some point on the span under consideration, the point being indicated by the lower-case letter.

C followed by one lower-case letter = weight in lbs. of any concentrated load which may be at the point indicated by the lower-case letter. This value may be taken directly from the moment table.

D followed by one lower-case letter = distance in feet between the point of location of the first concentrated load of the base loading and some other point indicated by the lower-case letter. When the point indicated by the lower-case letter is to the right of the point of location of the first concentrated load of the base loading this value may be taken directly from the moment table.

D followed by two lower-case letters = distance in feet between the two points indicated by the lower-case letters.

L = length in feet of span under consideration.

Ll = length in feet of left-hand span of two adjoining spans under consideration.

Lr = length in feet of right-hand span of two adjoining spans under consideration.

M followed by one lower-case letter = sum of moments in foot-lbs. of that portion of the base loading which is located to the left of the point indicated by the lower-case letter, about this same point. This value may be taken directly from the moment table.

M followed by three lower-case letters = sum of moments in foot-lbs. of that portion of the base loading which is located between

the points indicated by the first two of the lower-case letters, about some point indicated by the third of the lower-case letters, the moments of any concentrated loads which may be at the first two points (as indicated by the first two lower-case letters) being included.

R followed by one lower-case letter = reaction in lbs. due to the system of loading at the point indicated by the lower-case letter.

S followed by two lower-case letters = stress in lbs. due to the system of loading in the member indicated by the lower-case letters.

U = uniform load in lbs. per lineal foot of the base loading.

V followed by one lower-case letter = vertical shear in lbs. due to the system of loading, immediately to the left of the point indicated by the lower-case letter.

V followed by two lower-case letters = vertical shear in lbs. due to the system of loading in the panel indicated by the lower-case letters.

W followed by one lower-case letter = weight in lbs. of that portion of the base loading which is located to the left of the point indicated by the lower-case letter, the weight of any concentrated load which may be at the point in question being included. This value may be taken directly from the moment table.

W followed by two lower-case letters = weight in lbs. of that portion of the base loading which is located between the two points indicated by the lower-case letters, the weight of any concentrated loads which may be at the points in question being included.

FORMULAS PERTAINING TO BASE LOADING.

(See Fig. 1)

Distances.—The distance between two given points, x and y, on the base loading, is evidently equal to the distance between the first concentrated load and point y, minus the distance between the first concentrated load and point x; or expressing it algebraically,

$$Dxy = Dy - Dx \qquad (1)$$

Weights.—The weight of a portion of the base loading located between two given points, x and y (the weight of any concentrated loads which may be at the points in question being included), is equal to the weight of that portion of the base loading which is located to the left of point y (the weight of concentrated load, if any, at y being included), minus the weight of that portion of the base loading which is located to the left of point x (the weight of

concentrated load, if any, at x being included), plus the weight of any concentrated load which may be at point x.

Expressing this by symbols, we have,

$$Wxy = Wy - (Wx - Cx) \quad \ldots\ldots (2)$$

Moments.—The sum of the moments of a portion of the base loading located between two given points, x and y, about y (the moments of any concentrated loads which may be at the points in question being included), is equal to the sum of the moments of that portion of the base loading which is located to the left of point y about y, minus the sum of the moments of that portion of the base loading which is located to the left of point x about x, minus the product of the weight of that portion of the base loading which is located to the left of point x (not including the weight of any concentrated load which may be at point x) and the distance between points x and y.

The formula for this will be

$$Mxyy = My - Mx - (Wx - Cx)\ Dxy \quad \ldots\ldots (3)$$

The sum of the moments of a portion of the base loading located between two given points, x and y, about a third point z (the moments of any concentrated loads which may be at points x and y being included) is equal to the sum of the moments of that same portion about y, plus the product of the weight of that portion of the base loading which is located between points x and y (the weight of the concentrated loads, if any, at the points in question being included) and the distance between points y and z; or

$$Mxyz = Mxyy + Wxy\ Dyz \quad \ldots\ldots (a)$$

Substituting values as given by formulas (2) and (3), we get

$$Mxyz = My - Mx + Wy\ Dyz - (Wx - Cx)\ Dxz \quad \ldots\ldots (4)$$

The sum of the moments of a portion of the base loading located between two given points, x and y, about x (the moments of any concentrated loads which may be at the points in question being included), is equal to the product of the weight of that same portion and the distance between its center of gravity and point x; or

$$Mxyx = Wxy\ (Dxy - \frac{Mxyy}{Wxy})$$

$$= Wxy\ Dxy - Mxyy \quad \ldots\ldots (b)$$

Using equivalent values as shown by formulas (2) and (3) there results

$$Mxyx = Wy\ Dxy + Mx - My \quad \ldots\ldots (5)$$

The sum of the moments of a portion of the base loading located between two given points, x and y, about a third point w (the moments of any concentrated loads which may be at the points x

and y being included) is equal to the sum of the moments of that same portion about point x, plus the product of the weight of the portion of the base loading located between points x and y (the weight of any concentrated loads which may be at points x and y being included) and the distance between points w and x; or

$$Mxyw = Mxyx + Wxy\ Dwx \text{..............................(c)}$$

Using formulas (2) and (5), this reduces to

$$Mxyw = Wy\ Dwy + Mx - My - (Wx - Cx)\ Dwx \text{........(6)}$$

FORMULAS FOR SIMPLE BEAMS.

Reactions for Single Spans. (See Fig. 2.)—As the reaction at one support of a span is equal to the sum of the moments of all the loads on the span about the other support divided by the length of the span, it follows that the equation for finding the reaction at the left-hand support due to a given system of loading will be

$$Rl = \frac{Mlrr}{L} \text{..............................(d)}$$

Substituting for $Mlrr$ the value given by formula (3), viz., $Mr - Ml - (Wl - Cl)\ L$ and reducing, we have

$$Rl = \frac{Mr - Ml}{L} - (Wl - Cl) \text{..............................(7)}$$

In a similar manner by employing formula (5), the equation for finding the reaction at the right-hand support will be found to be

$$Rr = Wr - \frac{Mr - Ml}{L} \text{..............................(8)}$$

Reactions for Double Spans. (See Fig. 3.)—The reaction at the middle support of two adjoining spans, *Ll* and *Lr*, due to a given system of loading, is obviously equal to the right-hand reaction of span *Ll* due to the portion of the system of loading which is on span *Ll*, plus the reaction at the left-hand support of span *Lr* due to the portion of the system of loading which is on span *Lr*.

The portion of the system of loading on span *Ll* may be regarded as a separate system of loading for this span, and the reaction due to it at the middle support may be found by equation (8) by substituting point *m* for *r*, and *Ll* for *L*, the middle support of the double span being the right-hand support of span *Ll*.

The portion of the system of loading on span *Lr* may likewise be regarded as a separate system of loading for this span, and the reaction due to it at the middle support may be found by equation (7) by substituting point *m* for *l*, and *Lr* for *L*, the middle support of the double span being the left-hand support of span *Lr*.

However, if there be a concentrated load at the middle support (which will nearly always be the case if the maximum reaction is being sought) then, as a little consideration will show, the weight of this concentrated load would be taken into account twice by combining formulas (7) and (8).

Uniting these two formulas (after proper substitutions have been made as suggested above), subtracting *Cm*, and reducing, the result is

$$Rm = \frac{Mr - Mm}{Lr} - \frac{Mm - Ml}{Ll} \dots\dots\dots\dots\dots\dots (9)$$

If span *Ll* is equal to span *Lr*, this formula may be written

$$Rm = \frac{Mr + Ml - 2\,Mm}{Lr} \dots\dots\dots\dots\dots\dots (10)$$

Shears. (See Fig. 2.)—The vertical shear at any point on a given span is equal to the reaction at the left-hand support minus all the loads to the left of the point considered, or

$$Vp = Rl - Wlp + Cp \dots\dots\dots\dots\dots\dots (e)$$

By the aid of formulas (2) and (7) this will simplify to

$$Vp = \frac{Mr - Ml}{L} - (Wp - Cp) \dots\dots\dots\dots\dots\dots (11)$$

If there be a concentrated load at point *p*, formula (11) gives the vertical load at an infinitesimal distance to the left of the point. The vertical shear immediately to the right of the point is equal to the vertical shear as found by formula (11), minus the concentrated load at the point.

Bending Moments. (See Fig. 2.)—The bending moment at any point on a given span is the algebraic sum of the moments of all the forces (the reaction included) acting upon the span on either side of that point, the point being considered as the center of moments.

From this definition it follows that

$$Bp = Rl\ Dlp - Mlpp \dots\dots\dots\dots\dots\dots (f)$$

Replacing *Rl* with its equivalent value as given by formula (7) and *Mlpp* with that given by (3), in which latter equation must first be substituted for *x* and *y* points *l* and *p*, respectively, and canceling like terms, the result is

$$Bp = (Mr - Ml)\frac{Dlp}{L} + Ml - Mp \dots\dots\dots\dots\dots\dots (12)$$

If the point under consideration is the center of the span, formula (12) may be written

$$Bc = \frac{1}{2}(Mr + Ml) - Mc \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

FORMULAS FOR TRUSS AND THROUGH-GIRDER SPANS.

For truss spans (or through-girder spans) where the loads are transferred from the track to the trusses (or girders) through the stringers and the floor-beams, some of the formulas as developed for simple beams hold good only with certain restrictions, and others cannot be applied.

Reactions for Single Spans.—These formulas give the gross reaction. The net reaction is equal to the shear in the panel nearest the support. See formulas for shears.

Reactions for Double Spans.—The formulas for finding the reaction at the middle support for two adjoining spans as derived for simple beams hold true for truss and through-girder spans without restriction.

Shears. (See Fig. 4.)—The formulas for shears as given for simple beams do not hold true for truss or through-girder spans.

The vertical shear in any panel, as *o-q*, is uniform throughout the member for a given position of the base loading, even if there be some loads between points *o* and *q*, because these loads would not rest on, but would be carried to, the trusses at panel points *o* and *q* by means of the stringers and the floor-beams.

If the loads rested directly on the trusses, the shear formulas for simple beams could, of course, be applied; but as part of the loads between points *o* and *q* is transferred to *o* and the remainder to *q*, the vertical shear immediately to the left of *q* is increased by the amount of the loading between points *o* and *q* which goes to *q*.

This amount may be found by the use of equation (8), considering stringers between *o* and *q* to be simple beams, *o* being the left-hand, and *q* the right-hand support.

However, if there be a concentrated load at point *q*, this load would be taken into account twice by combining formulas (8) and (11), and should, therefore, be deducted from the result obtained by adding these two formulas.

Performing this addition (the necessary substituting of points in (8) and (11) having been done), and subtracting Cq the formula for finding the vertical shear in any panel *o-q*, will be

$$Voq = \frac{Mr - Ml}{L} - \frac{Mq - Mo}{Doq} \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Bending Moments. (See Figs. 4 to 8.)—Formulas (12) and (13) are applicable only when the point under consideration is a panel concentration point, or is located vertically above or below one.

The bending moment at a given point p located between two panel points, o and q, is equal to the bending moment at o, plus the product of the shear in panel o-q and the distance between points o and p.

By properly combining formulas (12) and (14) we get

$$Bp = (Mr - Ml)\frac{Dlp}{L} + Ml - Mo - (Mq - Mo)\frac{Dop}{Doq} \quad \ldots . (15)$$

CONCLUDING REMARKS.

The foregoing formulas and those given in connection with Figs. 1 to 8 (the latter can readily be derived by the aid of the former), of course, do not cover all cases that will arise, but for the designer who thoroughly understands stresses in trusses, it should be an easy matter to derive a formula which will apply to the problem at hand.

As should be self-evident, all formulas given herewith may be used in conjunction with any base loading whatsoever, provided the moment table has been made in the same manner as the accompanying one.

The designer will find it convenient to have the formula he desires to use in a conspicuous place, and alone to avoid confusing it with others. Copying it in his calculation book at the top of the page on which he intends to make his computations and drawing a blue or red line around it is a very desirable way of effecting this.

Instead of calculating at what distance from wheel No. 1 Ml, Mr, etc., should be read for a certain position of the base loading, an easier and quicker way to obtain this end is to lay off on a straight line, and to the same scale to which the spacing of the loads in the loading diagram has been drawn, the length of the span under consideration, marking the various points on it by the proper lowercase letters, as for instance l at left-hand support, r at right-hand support, etc. The moment table itself, if properly trimmed along its border lines, may be used as a scale in laying off the points by placing wheel No. 1 at left-hand support, as can easily be seen without going into further details. Having located the points necessary, the moment table may be moved back and forth to any desired position, and the called-for value in the formula to be used may be read without great difficulty.

If the moment table is not long enough to reach beyond right-hand support, Mr, Wr, etc., will have to be calculated, or an extension made to the moment table before proceeding any further. The latter alternative is perhaps always to be preferred because when once done it would not have to be done again, whereas the calculation of Mr, Wr, etc., would have to be made each time.

The formulas to be used where M and W values have to be calculated for a given point, v, located to the right of the last line, u, of the moment table are as follows:

$$Wv = Wu + Duv\ U \qquad (16)$$

$$Mv = Mu + Wu\ Duv + \tfrac{1}{2}\ (Duv)^2\ U \qquad (17)$$

Interpolation must be resorted to where M and W values are required at a point located a certain number of feet plus a fraction of a foot from wheel No. 1, or some approximation must be introduced, but this would require only a little additional work.

In handling the moment table many short-cuts will gradually suggest themselves to the user of the table, and no attempt will here be made to enumerate any of these.

A limited number of concrete examples are given with Figs. 2, 3, and 4. A study of the solutions of these problems will probably show in a more satisfactory manner than a wordy description possibly could, the simplicity of using a moment table of the kind presented herewith; and the attention of the reader is, therefore, called especially to this feature. In these examples no particular endeavor has been made to place the base loading so as to produce maximum stresses, the object being merely to illustrate the procedure.

The writer wishes to emphasize that he does not claim to be the originator of the accompanying form of moment table. Tables of similar form, perhaps not quite so extensive either in length or in detail, may be found in several text-books. The principal purpose of this article has been to show the advantage of a joint use of formulas and tables in the solution of live-load problems; and having the formulas systematically arranged, which to the best of the writer's knowledge no book has ever attempted nor intended to have, it is believed that this advantage is not purely imaginary.

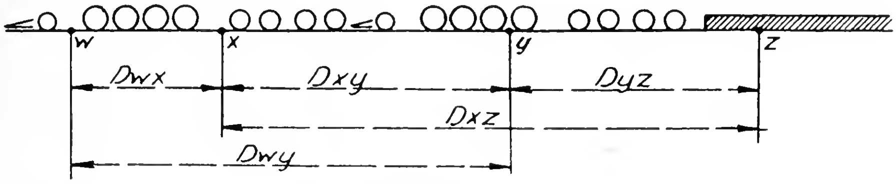


FIG. 1

GENERAL CASE

For any position of base loading.

$Wxy = Wy - (Wx - Cx)$

$Mxyy = My - Mx - (Wx - Cx)\,Dxy$

$Mxyz = My - Mx + Wy\,Dyz - (Wx - Cx)\,Dxz$

$Mxyx = Wy\,Dxy + Mx - My$

$Mxyw = Wy\,Dwy + Mx - My - (Wx - Cx)\,Dwx$

Note:

In these formulas the algebraic sum of $(Wx - Cx)$ may be read directly. If there be no concentrated load at x, $Cx = 0$ and $(Wx - Cx)$ becomes simply Wx, while if there be a concentrated load at x, $(Wx - Cx)$ will be equal to the W value on the preceding line. This evidently holds true for any formula in which $(W - C)$ values occur.

The above formulas are especially useful in deriving additional ones for any particular problem not covered by the formulas given in connection with Fig. 2-8.

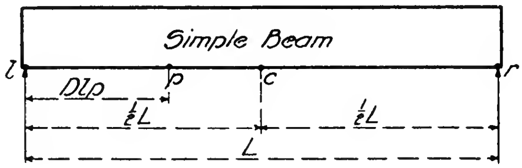


FIG. 2

GENERAL CASE	SPECIAL CASES	
For any position of Base loading	No loads beyond l	No loads beyond p
$Rl = \frac{Mr - Ml}{L} - (Wl - Cl)$	$= \frac{Mr}{L}$	
$Rr = Wr - \frac{Mr - Ml}{L}$	$= Wr - \frac{Mr}{L}$	
$Vp = \frac{Mr - Ml}{L} - (Wp - Cp)$	$= \frac{Mr}{L} - (Wp - Cp)$	$= \frac{Mr}{L}$
$Bp = (Mr - Ml)\frac{Dlp}{L} + Ml - Mp$	$= Mr\,\frac{Dlp}{L} - Mp$	$= Mr\,\frac{Dlp}{L}$
$Bc = \frac{1}{2}(Mr + Ml) - Mc$	$= \frac{1}{2}Mr - Mc$	$= \frac{1}{2}Mr$

EXAMPLE

Given: C. to C. bearings of a single-track deck girder = 100 ft.
Live Load = Cooper's E60, wheel #2 being located at left-hand support.

To find: (a) Left-hand reaction due to live load.
(b) Right hand reaction.
(c) Vertical shear at 10 ft. from left hand support.
(d) Bending moment at 25 ft. from left hand support.
(e) Bending moment at center of span.

SOLUTION

(a)
$Mr = 24,120,000'\#$
$-Ml = 120,000'\#$
$24,000,000'\# \div L(=100') = 240,000\#$
$-(Wl - Cl) = 15,000\#$
$Rl = 225,000\#$

(b)
$Wr = 426,000\#$
$Mr = 24,120,000'\#$
$-Ml = 120,000'\#$
$24,000,000 \div L(=100') = 240,000\#$
$Rr = 186,000\#$

(c)
$Mr = 24,120,000'\#$
$-Ml = 120,000'\#$
$24,000,000'\# \div L(=100') = 240,000\#$
$-(Wp - Cp) = 75,000\#$
$Vp = 165,000\#$

(d)
$Mr = 24,120,000'\#$
$-Ml = 120,000'\#$
$24,000,000'\# \times \frac{Dlp}{L}(=\frac{25}{100}) = 6,000,000'\#$
$+Ml = 120,000'\#$
$6,120,000'\#$
$-Mp = 2,614,500'\#$
$Bp = 3,505,500'\#$

(e)
$Mr = 24,120,000'\#$
$+Ml = 120,000'\#$
$24,240,000'\# \times \frac{1}{2} = 12,120,000'\#$
$-Mc = 7,404,000'\#$
$Bc = 4,716,000'\#$

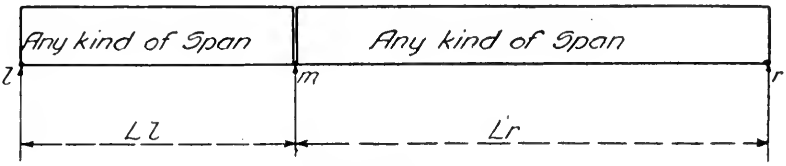


FIG. 3.

GENERAL CASE	SPECIAL CASES	
For any position of base loading	No loads beyond l	No loads beyond m
When Ll and Lr are not equal:		
$Rm = \frac{Mr-Mm}{Lr} - \frac{Mm-Ml}{Ll}$	$= \frac{Mr-Mm}{Lr} - \frac{Mm}{Ll}$	$= \frac{Mr}{Lr}$
When Ll and Lr are equal:		
$Rm = \frac{Mr+Ml-2Mm}{Lr}$	$= \frac{Mr-2Mm}{Lr}$	$= \frac{Mr}{Lr}$

EXAMPLE

Given: Two adjoining single-track spans (as shown in Fig. 3) the left-hand span being 50 ft long and the right-hand span 100 ft.

To find: Reaction per rail due to Cooper's E60 loading at middle support when wheel #11 is located at that point.

SOLUTION

$$
\begin{aligned}
Mr &= 52,513,500'\# \\
-\,Mm &= \underline{8,772,000'\#} \\
& \ 43,741,500'\# \div Lr\,(=100') = 437,415\#
\end{aligned}
$$

$$
\begin{aligned}
Mm &= 8,772,000'\# \\
-\,Ml &= \underline{420,000'\#} \\
& \ 8,352,000'\# \div Ll\,(=50') = \underline{167,040\#} \\
& \qquad Rm = 270,375\# \text{ Ans.}
\end{aligned}
$$

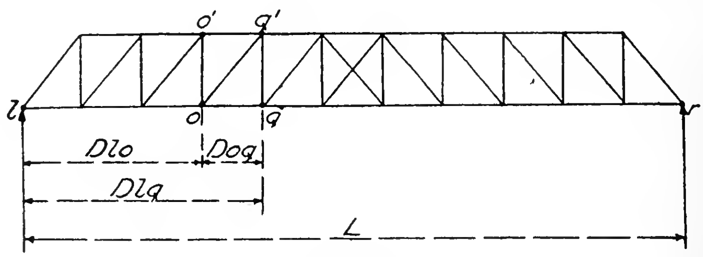


FIG. 4

GENERAL CASES	SPECIAL CASES	
For any position of base loading.	No loads beyond l	No loads beyond o
$Rl = \frac{Mr-Ml}{L} - (Wl - Cl)$	$= \frac{Mr}{L}$	
$Rr = Wr - \frac{Mr-Ml}{L}$	$= Wr - \frac{Mr}{L}$	
$Voq = \frac{Mr-Ml}{L} - \frac{Mq-Mo}{Doq}$	$= \frac{Mr}{L} - \frac{Mq-Mo}{Doq}$	$= \frac{Mr}{L} - \frac{Mq}{Doq}$
$Sqq' = \frac{Mr-Ml}{L} - \frac{Mq-Mo}{Doq}$	$= \frac{Mr}{L} - \frac{Mq-Mo}{Doq}$	$= \frac{Mr}{L} - \frac{Mq}{Doq}$
$Soq' = \left(\frac{Mr-Ml}{L} - \frac{Mq-Mo}{Doq}\right) \frac{Doq'}{Dqq'}$	$= \left(\frac{Mr}{L} - \frac{Mq-Mo}{Doq}\right) \frac{Doq'}{Dqq'}$	$= \left(\frac{Mr}{L} - \frac{Mq}{Doq}\right) \frac{Doq'}{Dqq'}$
$Soq = \left[(Mr-Ml) \frac{Dlq}{L} + Ml - Mq\right] \div Dqq'$	$= \left(Mr \frac{Dlq}{L} - Mq\right) \div Dqq'$	
$So'q = \left[(Mr-Ml) \frac{Dlo}{L} + Ml - Mo\right] \div Doo'$	$= \left(Mr \frac{Dlo}{L} - Mo\right) \div Doo'$	$= \frac{Mr}{L} \frac{Dlo}{Doo'}$

Note.
Above formulas hold true whether or not panels are of equal length

EXAMPLE

Given; A single-track through span of the type shown in Fig. 4 having 8 equal panels each 20 feet long. Distance between centers of chords = 25 feet

To find; Stress in diagonal in third panel from left-hand support of span when wheel #3 is located at right hand end of panel under consideration

SOLUTION

$Mr \div L = 26274000'^{\#} \div 160' = 164{,}212^{\#}$

$Mq \div Doq = 345000'^{\#} \div 20' = \underline{17{,}250^{\#}}$

$146{,}962^{\#}$

$\times \frac{Doq'}{Dqq'} = \frac{32'}{25'} = 188{,}111^{\#}$ Ans.

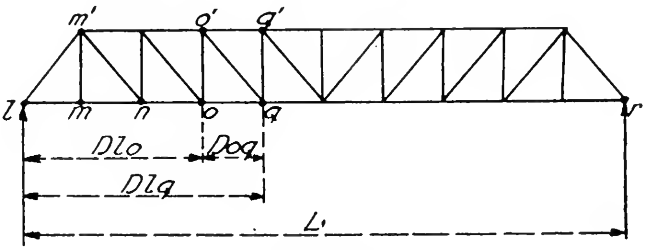


FIG. 5

GENERAL CASE	SPECIAL CASES	
For any position of base loading	No loads beyond l	No loads beyond o
$Rl = \frac{Mr-Ml}{L} - (Wl - Cl)$	$= \frac{Mr}{L}$	
$Rr = Wr - \frac{Mr-Ml}{L}$	$= Wr - \frac{Mr}{L}$	
$Voq = \frac{Mr-Ml}{L} - \frac{Mq-Mo}{Doq}$	$= \frac{Mr}{L} - \frac{Mq-Mo}{Doq}$	$= \frac{Mr}{L} - \frac{Mq}{Doq}$
$Slm' = \left(\frac{Mr-Ml}{L} - \frac{Mm-Ml}{Dlm}\right)\frac{Dlm'}{Dmm'}$	$= \left(\frac{Mr}{L} - \frac{Mm}{Dlm}\right)\frac{Dlm'}{Dmm'}$	
$Slm = \left(\frac{Mr-Ml}{L} - \frac{Mm-Ml}{Dlm}\right)\frac{Dlm}{Dmm'}$	$= \left(\frac{Mr}{L} - \frac{Mm}{Dlm}\right)\frac{Dlm}{Dmm'}$	
$Smm' = \frac{Mn-Mm}{Dmn} - \frac{Mm-Ml}{Dlm}$	$= \frac{Mn-Mm}{Dmn} - \frac{Mm}{Dlm}$	
$Soo' = \frac{Mr-Ml}{L} - \frac{Mq-Mo}{Doq}$	$= \frac{Mr}{L} - \frac{Mq-Mo}{Doq}$	$= \frac{Mr}{L} - \frac{Mq}{Doq}$
$So'q = \left(\frac{Mr-Ml}{L} - \frac{Mq-Mo}{Doq}\right)\frac{Do'q}{Doo'}$	$= \left(\frac{Mr}{L} - \frac{Mq-Mo}{Doq}\right)\frac{Do'q}{Doo'}$	$= \left(\frac{Mr}{L} - \frac{Mq}{Doq}\right)\frac{Do'q}{Doo'}$
$Soq = \left[(Mr-Ml)\frac{Dlo}{L} + Ml - Mo\right] \div Doo'$	$= \left(Mr\frac{Dlo}{L} - Mo\right) \div Doo'$	$= \frac{Mr}{L}\frac{Dlo}{Doo'}$
$So'q' = \left[(Mr-Ml)\frac{Dlq}{L} + Ml - Mq\right] \div Dqq'$	$= \left(Mr\frac{Dlq}{L} - Mq\right) \div Dqq'$	$= \frac{Mr}{L}\frac{Dlq}{Dqq'}$

Note.
Above formulas hold true whether or not panels are of equal length.

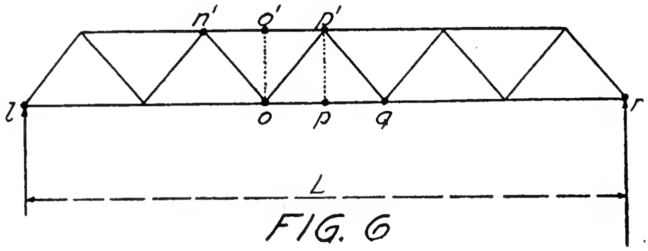


FIG. 6

GENERAL CASE	SPECIAL CASES	
For any position of base loading	No loads beyond l	No loads beyond o
$R_l = \frac{M_r - M_l}{L} - (W_l - C_l)$	$= \frac{M_r}{L}$	
$R_r = W_r - \frac{M_r - M_l}{L}$	$= W_r - \frac{M_r}{L}$	
$V_{oq} = \frac{M_r - M_l}{L} - \frac{M_q - M_o}{D_{oq}}$	$= \frac{M_r}{L} - \frac{M_q - M_o}{D_{oq}}$	$= \frac{M_r}{L} - \frac{M_q}{D_{oq}}$
$S_{op'} = \left(\frac{M_r - M_l}{L} - \frac{M_q - M_o}{D_{oq}}\right)\frac{D_{op'}}{D_{pp'}}$	$= \left(\frac{M_r}{L} - \frac{M_q - M_o}{D_{oq}}\right)\frac{D_{op'}}{D_{pp'}}$	$= \left(\frac{M_r}{L} - \frac{M_q}{D_{oq}}\right)\frac{D_{op'}}{D_{pp'}}$
$S_{p'q} = \left(\frac{M_r - M_l}{L} - \frac{M_q - M_o}{D_{oq}}\right)\frac{D_{p'q}}{D_{pp'}}$	$= \left(\frac{M_r}{L} - \frac{M_q - M_o}{D_{oq}}\right)\frac{D_{p'q}}{D_{pp'}}$	$= \left(\frac{M_r}{L} - \frac{M_q}{D_{oq}}\right)\frac{D_{p'q}}{D_{pp'}}$
$S_{n'p'} = \left[(M_r - M_l)\frac{D_{lo}}{L} + M_l - M_o\right] \div D_{oo'}$	$= \left(M_r\frac{D_{lo}}{L} - M_o\right) \div D_{oo'}$	$= \frac{M_r}{L}\frac{D_{lo}}{D_{oo'}}$
$S_{oq} = \left[(M_r - M_l)\frac{D_{lp}}{L} + M_l - M_o - (M_q - M_o)\frac{D_{op}}{D_{oq}}\right] \div D_{pp'}$		

Note;
Above formulas hold true whether or not panels are of equal length.

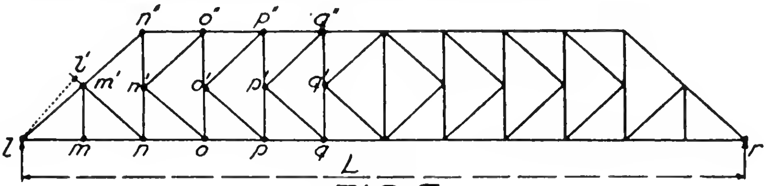


FIG. 7

GENERAL CASE	SPECIAL CASES	
For any position of base loading	No loads beyond l	No loads beyond o
$Rl=\frac{Mr-Ml}{L}-(Wl-Cl)$	$=\frac{Mr}{L}$	
$Rr=Wr-\frac{Mr-Ml}{L}$	$=Wr-\frac{Mr}{L}$	
$Vop=\frac{Mr-Ml}{L}-\frac{Mp-Mo}{Dop}$	$=\frac{Mr}{L}-\frac{Mp-Mo}{Dop}$	$=\frac{Mr}{L}-\frac{Mp}{Dop}$
$Slm'=\left(\frac{Mr-Ml}{L}-\frac{Mm-Ml}{Dlm}\right)\frac{Dlm'}{Dmm'}$	$=\left(\frac{Mr}{L}-\frac{Mm}{Dlm}\right)\frac{Dlm'}{Dmm'}$	
$Slm=\left(\frac{Mr-Ml}{L}-\frac{Mm-Ml}{Dlm}\right)\frac{Dlm}{Dmm'}$	$=\left(\frac{Mr}{L}-\frac{Mm}{Dlm}\right)\frac{Dlm}{Dmm'}$	
$Smm'=\frac{Mn-Mm}{Dmn}-\frac{Mm-Ml}{Dlm}$	$=\frac{Mn-Mm}{Dmn}-\frac{Mm}{Dlm}$	
$Sm'n=\left(\frac{Mn-Mm}{Dmn}-\frac{Mm-Ml}{Dlm}\right)\frac{Dlm}{Dll'}$	$=\left(\frac{Mn-Mm}{Dmn}-\frac{Mm}{Dlm}\right)\frac{Dlm}{Dll'}$	
$Sm'n''=\left(\frac{Mr-Ml}{L}-\frac{Mn-Ml}{Dln}\right)\frac{Dln''}{Dnn''}$	$=\left(\frac{Mr}{L}-\frac{Mn}{Dln}\right)\frac{Dln''}{Dnn'}$	
$Snn'=\frac{Mo-Mn}{Dno}-\frac{Mn-Ml}{Dln}$	$\frac{Mo-Mn}{Dno}-\frac{Mn}{Dln}$	
$Sn'n''=\frac{Mr-Ml}{L}-\frac{Mn-Ml}{Dln}$	$=\frac{Mr}{L}-\frac{Mn}{Dln}$	
$Sop=\left[(Mr-Ml)\frac{Dlo}{L}+Ml-Mo\right]\div Doo''$	$=\left(Mr\frac{Dlo}{L}-Mo\right)\div Doo''$	$=\frac{Mr}{L}\frac{Dlo}{Doo'}$
$So'p''=\left[(Mr-Ml)\frac{Dlo}{L}+Ml-Mo\right]\div Doo''$	$=\left(Mr\frac{Dlo}{L}-Mo\right)\div Doo''$	
$So'p=\left(\frac{Mr-Ml}{L}-\frac{Mp-Mo}{Dop}\right)\frac{Do'p}{Doo''}$	$=\left(\frac{Mr}{L}-\frac{Mp-Mo}{Dop}\right)\frac{Do'p}{Doo''}$	$=\left(\frac{Mr}{L}-\frac{Mo}{Dop}\right)\frac{Do'p}{Doo''}$
$So'p''=\left(\frac{Mr-Ml}{L}-\frac{Mp-Mo}{Dop}\right)\frac{Do'p''}{Doo''}$	$=\left(\frac{Mr}{L}-\frac{Mp-Mo}{Dop}\right)\frac{Do'p''}{Doo''}$	$=\left(\frac{Mr}{L}-\frac{Mo}{Dop}\right)\frac{Do'p''}{Doo''}$
$Sp'p''=\left(\frac{Mr-Ml}{L}-\frac{Mp-Mo}{Dop}\right)\frac{Do'o''}{Doo''}$	$=\left(\frac{Mr}{L}-\frac{Mp-Mo}{Dop}\right)\frac{Do'o''}{Doo''}$	$=\left(\frac{Mr}{L}-\frac{Mp}{Dop}\right)\frac{Do'o''}{Doo''}$
$Spp'=\left(\frac{Mr-Ml}{L}-\frac{Mp-Mo}{Dop}\right)\frac{Doo'}{Doo''}-\frac{Mq-Mp}{Dpq}+\frac{Mp-Mo}{Dop}$		

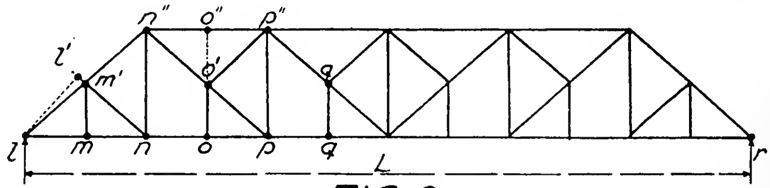


FIG. 8

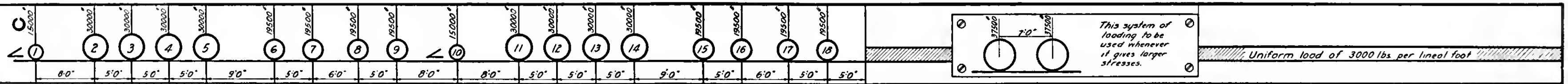
GENERAL CASE	SPECIAL CASE
For any position of base loading	No loads beyond l
$Rl=\frac{Mr-Ml}{L}-(Wl-Cl)$	$=\frac{Mr}{L}$
$Rr=Wr-\frac{Mr-Ml}{L}$	$=Wr-\frac{Mr}{L}$
$Vop=\frac{Mr-Ml}{L}-\frac{Mp-Mo}{Dop}$	$=\frac{Mr}{L}-\frac{Mp-Mo}{Dop}$
$Slm'=\left(\frac{Mr-Ml}{L}-\frac{Mm-Ml}{Dlm}\right)\frac{Dlm'}{Dmm'}$	$=\left(\frac{Mr}{L}-\frac{Mm}{Dlm}\right)\frac{Dlm'}{Dmm'}$
$Slm=\left(\frac{Mr-Ml}{L}-\frac{Mm-Ml}{Dlm}\right)\frac{Dlm}{Dmm'}$	$=\left(\frac{Mr}{L}-\frac{Mm}{Dlm}\right)\frac{Dlm}{Dmm'}$
$Smm'=\frac{Mn-Mm}{Dmn}-\frac{Mm-Ml}{Dlm}$	$=\frac{Mn-Mm}{Dmn}-\frac{Mm}{Dlm}$
$Sm'n=\left(\frac{Mn-Mm}{Dmn}-\frac{Mm-Ml}{Dlm}\right)\frac{Dlm}{Dll'}$	$=\left(\frac{Mn-Mm}{Dmn}-\frac{Mm}{Dlm}\right)\frac{Dlm}{Dll'}$
$Sm'n''=\left(\frac{Mr-Ml}{L}-\frac{Mn-Ml}{Dln}\right)\frac{Dln''}{Dnn''}$	$=\left(\frac{Mr}{L}-\frac{Mn}{Dln}\right)\frac{Dln''}{Dnn''}$
$Snn''=\frac{Mo-Mn}{Dno}-\frac{Mn-Ml}{Dln}$	$=\frac{Mo-Mn}{Dno}-\frac{Mn}{Dln}$
$Sn''o'=\left(\frac{Mr-Ml}{L}-\frac{Mo-Mn}{Dno}\right)\frac{Dn''p}{Dnn''}$	$=\left(\frac{Mr}{L}-\frac{Mo-Mn}{Dno}\right)\frac{Dn''p}{Dnn''}$
$So'p''=\left(\frac{Mp+Mn-2Mo}{Dnp}\right)\frac{Do'p''}{Do'o''}$	$=\left(\frac{Mp+Mn-2Mo}{Dnp}\right)\frac{Do'p''}{Do'o''}$
$So'p=\left(\frac{Mr-Ml}{L}-\frac{Mp-Mn}{Dnp}\right)\frac{Dn''p}{Dnn''}$	$=\left(\frac{Mr}{L}-\frac{Mp-Mn}{Dnp}\right)\frac{Dn''p}{Dnn''}$
$Snp=\left[(Mr-Ml)\frac{Dln}{L}+Ml-Mn\right]\div Dnn''$	$=\left(Mr\frac{Dln}{L}-Mn\right)\div Dnn''$
$Sn''p''=\left[(Mr-Ml)\frac{Dlp}{L}+Ml+Mn-2Mo\right]\div Dpp''$	$=\left(Mr\frac{Dlp}{L}+Mn-2Mo\right)\div Dpp''$
$Soo'=\frac{Mp+Mn-2Mo}{Dop}$	Note: In these formulas subdivided panels in any one main panel must be of equal lengths.
$Spp''=\frac{Mr-Ml}{L}-\frac{Mq-Mp}{Dpq}+\frac{Mp+Mn-2Mo}{Dnp}$	

Western Society of Engineers.
Vol. XXI. No. 1. January, 1916.
Marquardsen—The Advantages of a Combined Use of Tables and Formulas in the Computation of Bridge Stresses.

COOPER'S E-60 MOMENT TABLE

FOR ONE RAIL

DIAGRAM OF LOADING



D — DISTANCES IN FT. FROM WHEEL 1	W — SUM OF LOADS IN LBS	M — MOMENTS IN FT-LBS
0	15000	0
1	15000	15000
2	15000	30000
3	15000	45000
4	15000	60000
5	15000	75000
6	15000	90000
7	15000	105000
8	45000	120000
9	45000	165000
10	45000	210000
11	45000	255000
12	45000	300000
13	75000	345000
14	75000	420000
15	75000	495000
16	75000	570000
17	75000	645000
18	105000	720000
19	105000	825000
20	105000	930000
21	105000	1035000
22	105000	1140000
23	135000	1245000
24	135000	1380000
25	135000	1515000
26	135000	1650000
27	135000	1785000
28	135000	1920000
29	135000	2055000
30	135000	2190000
31	135000	2325000
32	154500	2460000
33	154500	2614500
34	154500	2769000
35	154500	2923500
36	154500	3078000
37	174000	3232500
38	174000	3406500
39	174000	3580500
40	174000	3754500
41	174000	3928500
42	174000	4102500
43	193500	4276500
44	193500	4470000
45	193500	4663500
46	193500	4857000
47	193500	5050500
48	213000	5244000
49	213000	5457000
50	213000	5670000
51	213000	5883000
52	213000	6096000
53	213000	6309000
54	213000	6522000
55	213000	6735000
56	228000	6948000
57	228000	7176000
58	228000	7404000
59	228000	7632000
60	228000	7860000
61	228000	8088000
62	228000	8316000
63	228000	8544000
64	258000	8772000
65	258000	9030000
66	258000	9288000
67	258000	9546000
68	258000	9804000
69	288000	10062000
70	288000	10350000
71	288000	10638000
72	288000	10926000
73	288000	11214000
74	318000	11502000
75	318000	11820000
76	318000	12138000
77	318000	12456000
78	318000	12774000
79	348000	13092000
80	348000	13440000
81	348000	13788000
82	348000	14136000
83	348000	14484000
84	348000	14832000
85	348000	15180000
86	348000	15528000
87	348000	15876000
88	367500	16224000
89	367500	16591500
90	367500	16959000
91	367500	17326500
92	367500	17694000
93	387000	18061500
94	387000	18448500
95	387000	18835500
96	387000	19222500
97	387000	19609500
98	387000	19996500
99	406500	20383500
100	406500	20790000
101	406500	21196500
102	406500	21603000
103	406500	22009500
104	426000	22416000
105	426000	22842000
106	426000	23268000
107	426000	23694000
108	426000	24120000
109	426000	24546000
110	429000	24973500
111	432000	25404000
112	435000	25837500
113	438000	26274000
114	441000	26713500
115	444000	27156000
116	447000	27601500
117	450000	28050000
118	453000	28501500
119	456000	28956000
120	459000	29413500
121	462000	29874000
122	465000	30337500
123	468000	30804000
124	471000	31273500
125	474000	31746000
126	477000	32221500
127	480000	32700000
128	483000	33181500
129	486000	33666000
130	489000	34153500
131	492000	34644000
132	495000	35137500
133	498000	35634000
134	501000	36133500
135	504000	36636000
136	507000	37141500
137	510000	37650000
138	513000	38161500
139	516000	38676000
140	519000	39193500
141	522000	39714000
142	525000	40237500
143	528000	40764000
144	531000	41293500
145	534000	41826000
146	537000	42361500
147	540000	42900000
148	543000	43441500
149	546000	43986000
150	549000	44533500
151	552000	45084000
152	555000	45637500
153	558000	46194000
154	561000	46753500
155	564000	47316000
156	567000	47881500
157	570000	48450000
158	573000	49021500
159	576000	49596000
160	579000	50173500
161	582000	50754000
162	585000	51337500
163	588000	51924000
164	591000	52513500
165	594000	53106000
166	597000	53701500
167	600000	54300000
168	603000	54901500
169	606000	55506000
170	609000	56113500
171	612000	56724000
172	615000	57337500
173	618000	57954000
174	621000	58573500
175	624000	59196000
176	627000	59821500
177	630000	60450000
178	633000	61081500
179	636000	61716000
180	639000	62353500
181	642000	62994000
182	645000	63637500
183	648000	64284000
184	651000	64933500
185	654000	65586000
186	657000	66241500
187	660000	66900000
188	663000	67561500
189	666000	68226000
190	669000	68893500
191	672000	69564000
192	675000	70237500
193	678000	70914000
194	681000	71593500
195	684000	72276000
196	687000	72961500
197	690000	73650000
198	693000	74341500
199	696000	75036000
200	699000	75733500

Fig. 9

IN MEMORIAM

ELMER JUERGENS, M.W.S.E.

Died April 1, 1915

Mr. Elmer Juergens was born in Chicago, May 23, 1881. He acquired his early education in the public schools of Chicago, graduating from the Chicago Manual Training School in 1899. He entered the servics of the Dearborn Foundry Company the same year, and in 1906 decided to enter the University of Illinois, to take the Civil Engineering course, graduating in the class of 1910. During the years he was studying at the University of Illinois his vacations were passed with the Dearborn Foundry Company, and upon his graduation he returned to the above company, where he remained up to the time of his illness.

He was elected a member of the Western Society of Engineers on March 6, 1912. Mr. Juergens was also a member of the Illini Club and Masonic Order.

He was a true gentleman, a loyal friend, and a man of high ideals. Beloved by many, the early termination of his career is very much regretted.

Mr. Juergens is survived by his widow, Florence W. Juergens.

Memoir prepared by Erastus Foote, Paul Willis and A. D. Mott, committee.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Annual Meeting, January 12, 1916

The Forty-sixth Annual Meeting of the Society (No. 924) was held Wednesday evening, January 12, 1916, in the Louis XVI room of the Hotel Sherman, Chicago. The meeting was attended by 252 members and guests.

During the course of the dinner music was rendered by the Commonwealth Edison Orchestra, under the leadership of Mr. Morgan L. Eastman, at the conclusion of which the Peoples Gas Light & Coke Company's Choral Society of sixty voices, and aided by the orchestra, rendered several selections.

Pictures of several of the Past-Presidents of the Society in their youth or babyhood days were shown on the screen, which brought great surprise to the subjects of the pictures and caused much merriment, the pictures having been procured from wives and relatives without the knowledge of the Past-Presidents.

Mr. Stineman had made cartoons of many of the important events happening in the Society during the year and these were also reproduced on the screen, to the great amusement of those in attendance. These cartoons portrayed a number of matters in connection with the history of the Society during the past year.

Retiring President Jackson turned the meeting over to Toastmaster Doctor Edwin H. Lewis, who performed the functions of that office in his usual pleasing and humorous manner. The other speakers of the evening were President-elect B. E. Grant and Mr. Samuell Insull, President of the Commonwealth Edison Company, who gave the principal address.

Retiring President Jackson announced, during the course of his remarks, the award of the Chanute medals for the best papers presented by members of the Society during the year 1914. (The report of the Committee on Award of the Chanute Medals will be found elsewhere in this Journal.) He also announced the gift of $1,000.00 from Past-President John W. Alvord as the foundation for an Honor Award, particulars of which will be found elsewhere in this Journal, as will also the other proceedings of the meeting.

The meeting adjourned about 11:00 P. M.

Extra Meeting January 24, 1916

An extra meeting (No. 925) in the interests of the Bridge and Structural Section was called to order at 7:30 P. M., Monday, January 24, 1916 (previous to the joint electrical meeting), with about 20 members present, and Mr. H. C. Lothholz, Chairman of the Section, in the chair.

Mr. Lothholz announced that the nominations for members of the Executive Committee for 1916 were in order.

The nominations were as follows:

FOR CHAIRMAN

Walter S. Lacher,
Frederick G. Vent.

FOR VICE CHAIRMAN

Norman M. Stineman.

FOR DIRECTOR

(1 to elect for 3 Years)

Herman E. Beckman,
Oscar F. Dalstrom,
Frederick G. Vent.

Election for the above officers to be held on February 14, 1916. There being no further business the meeting adjourned at 7:45 P. M.

Extra Meeting January 24, 1916

An extra meeting (No. 925), a joint meeting of the Electrical Section of

the Society and the Chicago Section of the American Institute of Electrical Engineers, was called to order at 8 P. M., Monday, January 24, 1916, with 80 members and guests in attendance, and Mr. T. Milton, Local Secretary, A. I. E. E., in chair.

Mr. Grant, who took charge temporarily, announced that the election of members of the Executive Committee of the Electrical Section for 1916 was in order, which resulted in the election of the following officers:

C. A. Keller for Chairman.
Wm. J. Crumpton for Vice Chairman.
E. N. Lake for Director for 3 Years.

Mr. C. A. Keller then introduced Mr. H. N. Foster, Superintendent of Traffic of the Chicago Telephone Company, who gave an illustrated talk with lantern slides and moving pictures on "The Modern Seven-League Boots," which was followed with explanatory remarks by Mr. Foster on the work of switchboards, etc., in the offices of the company. Several of the lantern slide cartoons which were used at the annual dinner of the Society were then shown for the benefit of those who were unable to see them on that occasion.

The meeting adjourned about 10:00 P. M.

E. N. Layfield, *Secretary.*

SECRETARY'S REPORT JANUARY 12, 1916

Board of Direction, Western Society of Engineers:

Gentlemen—I herewith respectfully present the Annual Report of the Proceedings of the Society for the year 1915.

The Membership of the different grades and of the Society as a whole, December 31, 1915, is shown in the following table:

Honorary Members	4
Members	776
Associate Members	237
Junior Members	124
Affiliated Members	41
Student Members	46
Total	1,228

Death has claimed the following members during the year:

James T. Bransfield, died January 21, 1915.
Elmer Juergens, died April 1, 1915.
Lindon W. Bates, Jr., died May 7, 1915.
William M. Hughes, died June 25, 1915.
Arthur M. Morgan, died June 26, 1915.
John H. Warder, died August 30, 1915.
Frederick A. Bergbom, died October 20, 1915.
Herbert M. Wheeler, died November 12, 1915.
L. G. Hallberg, died December 4, 1915.
A. Frederick Zick, died December 12, 1915.

Forty meetings were held during the year, as follows:

Monday, January 4th, Extra Meeting (No. 884). The annual meeting of the Hydraulic, Sanitary and Municipal Section. The paper by Charles H. Smith on "The Salem Conflagration" was read by the Assistant Secretary.

The 45th Annual Meeting and Dinner (No. 885) of the Society was held Wednesday, January 13th, at the Auditorium Hotel.

Thursday, January 14th, Smoker (No. 886). Illustrated lecture on "The California Exposition, the Grand Canyon and Yellowstone Park" was given by George F. Wheeler.

Monday, January 25th, Extra Meeting (No. 887). Joint meeting of the Electrical Section with Chicago Section A. I. E. E., being Annual Meeting of the Electrical Section. The paper was by N. W. Storer, "Economies in Power Consumption in Electric Railways."

Monday, February 1st, Regular Meeting (No. 888). K. G. Smith presented a paper on "Methods of Instruction in Engineering Exension."

Monday, February 8th, Extra Meeting (No. 889). W. S. Lacher presented a paper on "Retaining Walls on Soft Foundations."

Monday, February 15th, Extra Meeting (No. 890) of the Hydraulic, Sanitary and Municipal Section. Louis R. Ferguson presented a paper on "The Edison Fire."

Tuesday, February 23rd (No. 891), Joint Meeting of the Electrical Section Western Society of Engineers and Chicago Section A. I. E. E. Mr. Edward Schildauer gave a very interesting talk on "The Mechanical and Electrical Equipment of the Locks of the Panama Canal."

Monday, March 1st, Regular Meeting (No. 892). Professor D. W. Mead gave an illustrated talk on "Four Thousand Years of Engineering in China."

Monday, March 8th (No. 893). "Wind Stresses in the Steel Frames of Office Buildings," by W. M. Wilson and Albert Smith.

Tuesday, March 16th, Extra Meeting (No. 894). "Electrification: Pennsylvania and Norfolk & Western Rys.," George Gibbs; "In and About New York," Edwin B. Katte; "New York, New Haven & Hartford R. R.," W. F. Murray; "Chicago, Milwaukee & St. Paul R. R.," C. A. Goodnow.

Monday, March 22nd, Extra Meeting (No. 895). Joint Meeting of the Electrical Section, W. S. E., and Chicago Section A. I. E. E. "The Flow of Energy Through Transmission Lines," by Robert A. Philip.

Monday, March 29th, Extra Meeting (No. 896). Ladies' Night with a lecture by Mr. Asa Baldwin on "The International Boundary Survey."

Monday, April 5th, Regular Meeting (No. 897). "Engineering in War," by Col. W. V. Judson.

Monday, April 12th, Extra Meeting (No. 898). "The Pennsylvania Lift Bridge Over the Chicago River," by W. L. Smith and W. W. Priest. In the absence of the authors the paper was read by Mr. W. S. Lacher.

Friday, April 16th, Extra Meeting (No. 899). Students' Night. The meeting was addressed by B. F. Affleck, Isham Randolph, E. H. Lee, W. H. Finley, H. J. Burt, C. F. Loweth, C. A. Morse, Albert Reichmann, O. P. Chamberlain, H. S. Baker and W. W. DeBerard.

Monday, April 26th, Extra Meeting (No. 900). Joint Meeting of the Electrical Section of the W. S. E. and the Chicago Section of the A. I. E. E. "Electric Ship Propulsion," by W. L. R. Emmet.

Monday, May 3rd, Regular Meeting (No. 901). "The Development and Importance of an Adequate Engineering Department for a Public Service Commission," by Walter A. Shaw.

Monday, May 10th, Extra Meeting (No. 902). Bridge and Structural Section. Mr. C. M. Spofford presented a paper on "The Apportionment of Cost of Bridges Between Street Railways and Cities."

Monday, May 17th, Extra Meeting (No. 903), and the regular meeting of the Hydraulic, Sanitary and Municipal Section. Prof. F. H. Newell addressed the meeting on "Co-operation Among Engineers."

Monday, May 24th, Extra Meeting (No. 904). Joint meeting of the Electrical Section, Western Society of Engineers, and the Chicago Section, A. I. E. E. Mr. William B. Jackson and Mr. E. B. Ellicott on "Ten Years in Hydro-Electric Units."

Monday, June 7th, Regular Meeting (No. 905), with an address by Mr. Walter D. Moody on "The Present Status of the Chicago Plan."

Monday, June 21st, Extra Meeting (No. 906). The Electrical Section of the Western Society of Engineers with the Chicago Section of the American Institute of Electrical Engineers. Mr. H. B. Gear presented a paper on "The Application of the Diversity Factor."

Thursday, June 24th, Extra Meeting (No. 908). Bridge and Structural Section with a paper of Charles E. Bainbridge on "A Study of Grade Crossing Elimination in Cities."

Monday, June 28th, Extra Meeting (No. 908), which was a Smoker and the meeting was entertained by a talk by Mr. J. A. Rossiter on "The Philippine Islands."

Monday, September 13th, Regular Meeting (No. 909). Mr. H. S. Baker gave a talk on "The 1915 Camp for Engineer Troops of the National Guard at Belvoir Tract, Virginia."

Monday, September 20th, Extra Meeting (No. 910). A paper was presented by Mr. Ernest McCullough on "The Engineering Society, Its Past, Present and Its Future Activities."

Monday, September 27th, Extra Meeting (No. 911), in the interests of the Hydraulic, Sanitary and Municipal Section. Prof. Earle B. Phelps addressed the meeting on "The Investigations of the International Joint Commission on the Pollution of Boundary Waters."

Monday, October 4th, Regular Meeting (No. 912), was Ladies' Night. "Indians of the Southwest," by Ernest S. and Miss Mildred Rice.

Monday, October 11th, Extra Meeting (No. 913). Hydraulic, Sanitary and Municipal Section. Col. C. McD. Townsend presented a paper on "The Currents of Lake Michigan and Their Influence on the Climate of the Neighboring States."

Monday, October 18th, Extra Meeting (No. 914). Hydraulic, Sanitary and Municipal Section. "A Short Description of Some of the Construction Features of the Greater Winnipeg Water Supply," by James H. Fuertes.

Monday, October 26th, Extra Meeting (No. 915). Joint meeting of the Electrical Section, Western Society of Engineers, and the Chicago Section, American Institute of Electrical Engineers. Dr. C. P. Steinmetz, "Illumination."

Tuesday, November 2d, Regular Meeting (No. 916). Mr. L. E. Johnson presented a paper on "The Railroads and the Public."

Monday, November 8th, Extra Meeting (No. 917). Bridge and Structural Section. A paper was presented on "The Design of a Railway Pontoon Bridge" by Mr. H. J. Hansen.

Monday, November 22d, Extra Meeting (No. 918). Informal dinner meeting at the Hotel Sherman. Mr. Leonard A. Busby presented a paper on "The Regulation of Public Utilities."

Monday, November 29th, Extra Meeting (No. 919). "The Deflection of Trusses," by E. H. Casper and C. J. Kennedy, and "The Use of Influence Lines," by R. W. Flowers and H. N. Jones.

Monday, December 6th, Regular Meeting (No. 920). Smoker. A talk by Ernest McCullough on "The Work of the Artillery (Battery B)."

Monday, December 13th, Extra Meeting (No. 921). Address by Dr. E. V. Hill on "Ventilation."

Monday, December 20th, Extra Meeting (No. 922). Paper presented by W. F. M. Goss on "Electrification of Chicago Railway Terminals."

Wednesday, December 29th, Extra Meeting (No. 923). Joint meeting of the Electrical Section, Western Society of Engineers, and the Chicago Section, American Institute of Electrical Engineers. Mr. Frank J. Sprague presented a paper on "Naval Preparedness and the Civilian Engineer."

Attention is called to the December issue of the Journal, which is an Index to Volumes 1-20, inclusive (1896-1915), or in other words a complete index for the Journal from the date of publication to the end of the year 1915. This was compiled with as great care as was possible under the circumstances and it is hoped that it will prove of much value and convenience to the members of the Society and the readers of the Journal.

Respectfully submitted,

E. N. Layfield, *Secretary.*

LIBRARIAN'S REPORT

To the Board of Direction, Western Society of Engineers, Chicago, Illinois:

Gentlemen—The Librarian reports that during the year 1915 there has been a continued growth and use of the Library of the Society. The increase of accessioned volumes has been 246, making a total number of accessioned volumes in the Library of 9,949. This does not include a large number of pamphlets and reports which are bound in paper and which are taken care of

under a separate head, but which are available to users of the Library. There is quite a number of bound volumes on hand which have not yet been accessioned because of pressure of other work, but this work will soon be attended to and the books placed on the shelves.

E. N. Layfield, *Librarian.*

REPORT OF CHANUTE MEDAL AWARDS

Board of Direction, Western Society of Engineers, Chicago, Illinois:

Gentlemen—Your committee appointed to canvass the papers presented before the Society during the year 1914 and make recommendations for the award of the Chanute medals begs leave to make the following report:

The papers presented do not readily fall into the three classes of civil, mechanical and electrical engineering. There were no papers on electrical engineering presented by members of the Society.

Following precedents heretofore established and in accordance with rulings of the Board upon this matter, your committee recommends as follows:

To Andrews Allen for his paper on "Engineering Opportunities of Our Coal Mining Fields," which we place in the classification, "General Engineering."

To N. M. Stineman for his paper on "Reactions in a Three-Legged Stiff Frame With Hinged-Column Bases," under the classification, "Civil Engineering."

To H. E. Goldberg for his paper on "Arithmetical Machines," under the classification, "Mechanical Engineering."

Respectfully submitted,
(Signed) C. Kemble Baldwin,
L. K. Sherman,
H. B. Gear.

REPORT OF JUDGES OF ELECTION, WESTERN SOCIETY OF ENGINEERS, JANUARY 7, 1916

The undersigned Judges of Election, having canvassed the ballots cast for officers of the Western Society of Engineers for the year 1916, have the honor to report as follows:

Total number of votes cast	479
Total number of ballots rejected as irregular	12
Total number rejected as not qualified to vote on account of non-payment of dues	20
Total number of ballots counted	447
Number of votes cast for President:	
C. B. Burdick	136
H. J. Burt	147
B. E. Grant	163
Number of votes cast for First Vice-President:	
C. H. Cartlidge	415
Number of votes cast for Second Vice-President:	
D. W. Roper	412
Number of votes cast for Third Vice-President:	
F. H. Newell	188
L. K. Sherman	156
M. B. Wells	81
Number of votes cast for Treasurer:	
C. R. Dart	414
Number of votes cast for Trustee for three years:	
E. T. Howson	164
Ernest McCullough	274

Respectfully submitted,
M. M. Fowler,
J. H. Heuser,
C. W. Brooks,
Judges of Election.

Scattering votes, 1.

PROCEEDINGS OF ANNUAL MEETING AND DINNER JANUARY 12, 1916

Retiring President Jackson: We will be led in the invocation by Dean Lewis.

(Invocation by Dean Lewis.)

(During the course of the dinner music was rendered by the Commonwealth Edison Orchestra, and stereopticon slides were projected upon the screen, in caricature of various members of the Society, and so forth. After one of the songs, the President said):

Retiring President Jackson: Gentlemen, I wish to announce that this song was written for this occasion, the music by Mr. Eastman and the words by Mr. James N. Hatch.

* * * *

Retiring President Jackson: Gentlemen, we are now going to be favored with a song by the Peoples Gas Company Choral Society. We have just been hearing what the Commonwealth Edison Company's orchestra and its leader can do—and its General Manager you may hear about later—and we are now going to hear what the gas company's singers can do.

(Song was rendered by the Choral Society.)

Retiring President Jackson: Gentlemen, to show you how much confidence I have in our toastmaster, I am going to introduce him before taking the opportunity to say anything myself. To this audience it is really not necessary to introduce Dr. Lewis, on account of our already pleasant acquaintance with him. And we shall all be glad to hear him again. Dr. Lewis.

Toastmaster Lewis: Mr. President and Gentlemen—It gives me keen pleasure to be admitted to this presence, because I am not an engineer in any sense of the word, though long associated with engineers. But no man, I think, could fail to respond to at least two things which are in evidence here tonight. First, the beautiful balance and synchronizing—synchronizing both physical and spiritual—of the music which we have heard—the orchestra and also the Choral Society. I understand that Mr. Eastman is a load dispatcher, and I doubt if he ever dispatched any load with more distinction than he has dispatched this one tonight.

(Laughter and applause.)

And as for Mr. Hatch, he has arranged words beautifully here, and a great thought, and that thought comes home to me as I look upon this body of men.

No man could be a good citizen of Chicago who did not thrill to this presence, to this body of men, and the history that they represent, for in a sense we have here the men who have been the protagonists of Chicago in her struggle with Nature. I am in the presence of a fine body of wrestlers, old and young. It is an athletic occasion, whether you have struggled in the field of the infinitely small, with micrometric accuracy there, or whether you have dealt with fields which are measured by light years, it is all the same, you have been doing something for good old Chicago. And the words which Mr. Hatch has put down here, in which he speaks of Electra as the fair Queen of the Pleiades, suggest to me that while we still have wars and rumors of wars, and while one nation will declare that this or that nation is her only enemy, the simple fact remains that the human race has no enemy except Nature, and Nature would rather lose than win in her struggle with us. To be sure, she is a pretty hard task-master, and the mother of taskmasters. She is the mother of this terrible "Swamp King" who is mentioned here. But we, too, are her children, and she likes to see us put up a good scrap. And so we seem to be in the presence of the defenders of the city.

As for this program, I have glanced over it. It is not very long in names. It is rather weighty in names, but not very long, and I do not think that the next two speakers are my proper prey. They are both flowers, one a flower

which has gathered full perfume and is now slowly passing into seed (laughter); the other, a tender flower which requires very delicate handling.

The first man is going to speak, and then he will introduce the second man, who will make you a whole lot of promises. And I have no doubt that at the end of those promises you will respond with your unspoken, solemn promise to give him your co-operation. If you don't do it in words, you will indicate it, according to the spirit of the evening, by a strong current of electricity passing down the arms and producing a sudden contact between the palms (laughter). And in the meantime I surrender the honor accorded me to the Bayard *sans peur et sans reproche* now sitting at my right hand (applause).

Retiring President Jackson: I will call upon our Secretary, Mr. Layfield, to give us an abstract of the Annual Reports. That sounds fairly long, but he says it will be very short. Mr. Layfield (applause).

Secretary Layfield: I have a very distinct recollection of hearing Mr. Warder, who is no longer with us, give abstracts of Annual Reports, and the gentlemen who were listening, having been entertained by music and other varieties of entertainment, and being in expectancy of still other kinds of entertainment, did not listen with very much patience to the figures. And I have some recollection of having heard them tell him to cut it short, as it would appear in the Journal, and so forth. So I am going to be very brief and content myself with reading a list of those whose names have been stricken by death from our roll during the past year, and certain figures which will be very brief.

(The Secretary thereupon read excerpts from his report.)

ADDRESS OF RETIRING PRESIDENT JACKSON

Gentlemen: Fifteen years ago President Octave Chanute presented to the Society an endowment, the income from which was to be used to provide annually three medals to be awarded, one to the member presenting the best paper in civil engineering; one for the best paper in mechanical engineering; and one for the best paper in electrical or general engineering.

I have here the report of the Chanute Medal Committee, that committee consisting of Mr. C. Kemble Baldwin, Mr. L. K. Sherman and Mr. H. B. Gear, in which your Board of Directors has concurred.

I am going to ask Mr. N. M. Stineman to doff for the moment his usual cloak of modesty and come here, if he will, and permit me to present him with one of these awards (applause).

(Mr. Stineman came forward.)

Retiring President Jackson: Mr. Stineman, you have been awarded the 1915 Chanute Medal for civil engineering papers on account of your splendid paper treating of "Reactions in Three-Legged Stiff Frames With Hinged-Column Bases." And before taking pleasure in placing this in your hand, I wish to call the attention of our audience to the versatility of this recipient, who, I understand, is mostly responsible for the cartoons that you have seen on the curtain this evening (laughter and applause). I understand that he and Mr. Axel are responsible for them, and I think that one of these days you will doubtless see Mr. Axel coming to receive one of these awards. I take pleasure in presenting you with the certificate of award, Mr. Stineman. It is not possible for us to have the medals struck until after the names of the recipients are known, since the name is, in each case, cut in the die and we cannot therefore present the medal at this time.

I am now going to ask Mr. Hyman Eli Goldberg if he will step this way for a moment, and permit me to make an award to him.

(Mr. Goldberg came forward.)

Retiring President Jackson: Mr. Goldberg, I find that you have been awarded the medal on account of mechanical engineering for your paper on "Arithmetical Machines," and I would be pleased to hand you your certificate if it had not slipped down here (laughter) behind the speaker's platform (laughter). I will be obliged to present it to you later (laughter and applause).

I am not going to be placed in this same embarrassing position on account of the next award, since we regret that Past-President Andrews Allen, to whom the award on account of general subjects has been made, for his paper on "Engineering Opportunities in the Coal Mining Fields," is not present.

I believe that as the Retiring President I may now occupy a few moments of your time in expressing my deep obligation to you for having given me the opportunity to preside over this great Society during the past year, and also to make any further remarks that I may have on my mind.

We suffered a severe loss during the past year in the death of our honored Secretary, Mr. Warder, who for so long guided the activities of this Society with such devotion, and who, not having any children of his own, really made the Western Society of Engineers his child. And I think that we can feel that we owe a great deal to Mr. Warder for the high place in which the Western Society of Engineers now stands amongst the great technical societies of the country.

But there is a bright spot in this situation, because we are certainly to be congratulated in having been able to fill Mr. Warder's office with so effective a successor as Mr. Layfield (applause).

The problem, if I may so call it, of what constitutes the ethics of the engineering profession, that is, what should be the relations of the engineer to his profession, to his client, to his work, to his fellow engineer, and to his fellow man, has always been a most interesting one to me. The engineer has broad obligations in each of these directions. And it is no small task for one to lay down in concrete form the rules by which he should be guided. I am of the opinion that the engineering societies should be the proponents and special champions of engineering ethics, since their activities should in a sense represent the crystallization of the ethics of the engineering profession. It will, therefore, be appreciated that when one of our fellow members early in my term of office expressed to me his feeling that the Western Society of Engineers possibly did not have due regard for ethical procedure, that I said I would appoint a committee to consider the matter.

I appointed two committees; one, a Committee on Public Relations, with two of our Past Presidents and several other members who have done splendid work during the past year in advising the Board of Direction, in the best way to proceed in matters having to do with public relations. I also appointed a committee of three of our Past Presidents and two of our other members—to act as a balance wheel (laughter)—to decide whether it is advisable for the Western Society of Engineers to have a code of ethics, and if so to report to your board an effective code.

This committee decided the question in the affirmative, and it has submitted for your consideration a remarkable code of engineering ethics, or declaration of ethical principles. This is to be published in the next issue of the Journal, and I hope that no one of you will fail to carefully read it. We will be glad to have your earnest suggestions for the use of our committee, as we wish this code to have the fullest consideration before it is finally sent out for your formal adoption.

And now I come to a matter somewhat related to the foregoing, but which I think I can best present to you in the words of the author. I asked him to present the matter to you, but he felt that he would prefer to have me do so. (Reads letter from Mr John W. Alvord):

The President and Board of Direction, Western Society of Engineers,
Gentlemen:

"It has long been my observation that there are numerous instances where the engineer serves the public amid many difficulties, and often in inconspicuous ways, but with such ability that he accomplishes some particularly valuable results for the benefit of the community. Such achievements are only known, and not always properly acknowledged even by the profession to which he belongs. And they not infrequently entirely escape public notice.

"Further, it is well known that great benefits often accrue to the public at large through valuable improvements in the arts and their adaptation to the public use and need, and that these improvements are at times given by engineers to the public use without personal reward or gain.

"Finally, there is a class of engineers who, although substantially rewarded in a material way by the success of their work, nevertheless have accomplished so much for the world about them in vitally important and far-reaching ways that they are deserving further of special honor for their accomplishments. It is not always clearly perceived that almost all engineers serve the public directly or indirectly, and the field for useful public service is therefore about as wide as the profession. And it would appear that it is one of the important duties of engineering societies to point out to their membership and to the public such instances of engineering and administrative skill as seem to have unusual merit in order that honor may properly be accorded where it is due.

"Being desirous of promoting a better appreciation by the public of able work accomplished by engineers for the public welfare, and further, of encouraging among engineers themselves a broader understanding of their opportunities for public usefulness, I desire to see established by the Western Society of Engineers an honor award by medal or other tribute to be annually presented to that engineer whose particular work in some special instance, or whose services in general have been noteworthy for their merit in promoting the public good. I should be pleased if the recipient of this honor be not limited by Western Society membership, or, in fact, be restricted by any society or locality requirements. The only qualifications suggested are that he be an engineer of some reasonable degree of professional skill or administrative attainment. It would appear that the award will serve its purpose wisely if at times it was worthily bestowed upon comparatively little-known instances of public and professional devotion, as well as at other times upon more conspicuous services.

"I trust, therefore, that the Western Society of Engineers through its Board of Direction, may be willing and enabled to administer some program of this kind in such manner and in such instances as from time to time may seem to the Board of Direction best and most fitting. And for the purpose of enabling the Society to have an income sufficient to at least make a beginning, I take pleasure in donating to it unreservedly the sum of one thousand dollars in securities.

"Respectfully submitted,

"John W. Alvord."

(Applause and cries of "Alvord, Alvord." Continued applause.)

Retiring President Jackson: Will you say a few words, Mr. Alvord? (Applause.)

Past-President Alvord: Mr. President and Gentlemen—I do not know that I can add anything to what I have said in the letter, except, perhaps, the thought that a medal is a very little thing in itself, but it can be made a splendid thing if the spirit of a great Society and a great profession endow it with an honor which makes it intensely valuable to its recipient. And I trust that you all feel that this spirit and this honor will always go with this tribute. I thank you. (Applause.)

Retiring President Jackson: I have the securities with me that Mr. Alvord placed in my hands, and I had hoped to be able to turn them over to our treasurer this evening, but, unfortunately, Treasurer Dart was unable to be here on account of serious illness in his family, and I will consequently turn them over to the Secretary (handing securities to Secretary Layfield).

Your Board of Direction has accepted this gift with heartfelt thanks on behalf of the Society, and has pledged itself to see that suitable plans are promptly developed for its proper administration.

This is the third donation of one thousand dollars which our Society has received, the first by our honored Past-President and Honorary Member, Octave Chanute; the second by Past-President Arnold, and the third, this one, by Past-President Alvord.

I hope that this may indeed be, in accordance with the wishes of the donor, but the beginning of a much larger fund that may come into the hands of the Society for this worthy prize. For, as I gather the thought of the donor, this prize shall be given for real worth; that notoriety and the acclaim of the world will have nothing to do with it, but the man, the modest engineer who has accomplished something that is really worthy of mankind, shall receive this prize regardless of any knowledge or foreknowledge that the world may have of his great work.

And now, before introducing our new President, it is proper, and fortunately always a pleasure for a President who will soon be a Past-President of the Western Society of Engineers, to cordially thank his Board of Direction and his committees for their hearty co-operation during his administration. For it is only necessary for a person to be the president of the Western Society of Engineers, or some other important engineering society, to learn what men will do for a principal without expectation of direct gain. When one becomes a member of the Board of Direction of any one of our important engineering societies he obtains a high appreciation of the solidity of the great engineering societies, and their tremendous importance to the engineering profession.

And now, Mr. Grant, I believe that every President of the Western Society of Engineers, when he is about to retire from the executive chair, has a deep feeling of regret on account of the many things that he was unable to accomplish in the brief year of his presidency. But I am happy to say that I turn the high office of President over to you with the Society operating smoothly and effectively, and wish you a most pleasant and successful year as President.

I herewith formally turn over to you the official gavel of the Western Society of Engineers (applause. Three cheers were given for President Grant).

ADDRESS OF PRESIDENT GRANT

Fellow Members—The newly elected officers of the Society desire to say that they appreciate the very high honor that has been conferred upon them, and make one pledge—that of loyalty, to the service of this Society. And, notwithstanding the remarks of Mr. Lewis, I believe that is the only promise that I make tonight.

As many of you know, this Society is one of the oldest engineering societies in America. It was organized in May, 1869, as the "Civil Engineers Club of the Northwest." It is said that twelve of the most eminent engineers in this section of the country met to form the organization. Their idea of geography is plainly indicated by the name adopted. It is interesting to note that nearly all the meetings previous to the fire of 1871 were held at the Sherman House. And so you see that this Society had the Sherman House habit very early in its youth (laughter).

At the time of this organization, 1869, the city of Chicago was approximately one-tenth of its present size, both in area and population.

The marvelous growth of this city and the great region for which it is the natural center has occurred since the birth of this Society, and it is by no means an accident that the great progress of this community and the development of the Western Society of Engineers have been coincident.

If you read the history of the city you will find that members of the Western Society of Engineers held controlling positions in the planning and building of its waterworks, sewer, paving and lighting systems—and that its transportation system, both local and through, its parks and its drainage canal have been largely dependent on the efforts of our members.

The greatest mileage of elevated tracks and the greatest railroad yards in the United States are the work of members of the Western Society of Engineers.

The plans for skyscrapers in the past and subways in the future have been the work of Western Society Engineer members.

We also find our members prominently identified with the work of civic and military organizations and of the engineering colleges. You will doubtless recall the names of the engineers who have been factors in the progress and development of the territory of the "Northwest," which our Society in its early days considered to be its field.

It would be a great task to make a complete list of their names, with even a concise statement of their activities, but it might be a good thing if the Society could have a historian to collect the facts concerning the early life of the Society and put them into the record. Some work of this kind can be done at the present time which will be difficult or impossible in the near future.

When you came to the city today it is probable that you traveled on a railroad of which the general manager and the chief engineer are members of this Society; that you crossed bridges designed by one member and built by another; that when you left the terminal station you traveled over pavements planned by one member; to an office building that from foundation to roof was largely the result of the work of other members.

It may be that you will say these things are obvious, but it is the obvious thing that we often fail to see and appreciate.

Certainly the letters M. W. S. E. are not printed on the work of our members so that he who runs may read.

It has been my very good fortune to know some men of very fine character during my twenty-five years' membership in the Western Society.

One of the best was our Secretary, Mr. Warder, who died August 30, 1915.

He had many of the qualifications that are necessary to fill the position successfully—technical training, tactfulness, initiative, some business ability and a great persistence.

For nearly fifteen years of the most active period of the Society's life he was the energetic Secretary who had much to do with the Society's growth and success.

The Society now has a membership of almost exactly one hundred times the number at its first meeting nearly 47 years ago. Its membership ought to be two hundred times that number. The material for such an increase is right at hand.

The colleges of this and the neighboring states turn out annually several hundred engineering graduates and it seems to me that it would be the part of wisdom to make some serious effort to enlist these young men who will in a few years be carrying the burdens and the honors of the profession.

Now, in conclusion, just a word about the coming year. If each one will do a little work for the Society we will have the most successful year in our history. We must each one think of it, not as "a Society," or "your Society," but as "*our* Society." Then, after thinking of it in this way, the next logical thing to do is to act for it.

Will you try to do a little more for the Society this year than you did last year? (Applause.)

Past-President C. F. Loweth: Mr. Toastmaster—The Retiring President of this Society and the incoming President and the Secretary have spoken glowing words of tribute to our Past Secretary, Mr. J. H. Warder. They are well deserved, everything that has been said. And I am sure, Mr. Toastmaster, that the members of this Society here assembled would be very glad to have the opportunity by a rising, silent toast, of expressing their tribute to his memory. And I so move you.

Toastmaster Lewis: At this point we will rise and toast the memory of the dead—J. H. Warder.

(Silent toast to the memory of J. H. Warder.)

Toastmaster Lewis: It occurs to me that after this fine beginning of the new administration, this very organic and very relevant beginning, you

might like to know the names of the other members of the administration —the other officers if you have them, Mr. Jackson.

Retiring President Jackson: It was a terrible oversight that I failed to call your attention to the handsome countenance of Mr. Charles H. Cartlidge here at my left (applause), who was elected First Vice-President for the ensuing year. And just to his left you will see the smiling countenance of Mr. Denney W. Roper (applause), our new Second Vice-President. I do not know whether the first name should indicate that he is an Irishman or whether the last name should indicate that he is something else (laughter). As Third Vice-President we have Frederick H. Newell, who unfortunately was unable to be here. And for Treasurer, we have our fine Treasurer, Mr. Carlton R. Dart (applause).

Toastmaster Lewis: Now we shall have the pleasure of hearing once more from our musical supporters. We are to have a choral song accompanied by the orchestra. And I am instructed to say that after this final favor, this very great favor, if any of the young men feel that they must go, they are perfectly free to do so.

(Music by the Choral Society and the Orchestra.)

(Great applause and cheers.)

Toastmaster Lewis: Gentlemen, I give you the orchestra and the Choral Society!

(Toast to the Orchestra and the Choral Society; and great applause.)

Toastmaster Lewis: There is a kodak which is a kodak. They say, "If it is not an Eastman, it isn't a kodak." (Laughter.) I have been much amused with the clever way in which your Retiring President has tried to keep in office a little longer. It is a trick of retiring presidents. Sometimes it works and sometimes it does not (laughter). First, he forgot the Vice-Presidents of the new administration, and he just now appealed to me to let him make another speech and announce to you that the most important office of all, that of Trustee, had been won by Mr. Ernest McCullough (applause), but he does not get a chance to make a speech any more (laughter).

Last Saturday afternoon I was nursing a cold, and the telephone rang and I went to the telephone and a voice said, "This is the Western Society of Engineers." I said, "It may be, but if so you are far more unanimous than usual." (Laughter.) "Well," he said, "I am the acting Secretary." He had a voice which sounded as if he might be *persona grata* with the ladies. And I said, "Well, you are acting, all right. What is the matter?" (Laughter.) "Well," he said, "we want you to come down here and be Toastmaster next Wednesday." I said, "Never again." (Laughter.) He said, "Why?" And I said, "A great many things. One is, I have to ride in on the Oak Park elevated train, and I have a cold." (Laughter and applause.) "Well, he says, "we will send you a taxicab." I said, "That is nice. I have heard of them. I never rode in one. But I am stuck on the Oak Park 'L,' because I am so often stuck on it." (Laughter.) He said, "Don't shoot the organist, he is doing the best he can." I said, "I don't know what you are talking about; I am going to hang up the receiver." He said, "Don't hang up the receiver, or you won't have anybody to introduce next Wednesday night." (Laughter and applause.) So I said, "I know whom you mean now, but there is no such man. You ought to know that there is no such person as that man. That man is only a symbol. He is an abstraction. He is a power that walks in darkness. He is the soul of a corporation, and everybody knows that a corporation has no soul." (Laughter.) I said, "You have only to look at his name to see that he is not human. The first name is a prophet, and following the prophet comes a technical electrical term." I said, "That is always the motto of an electrical corporation—'profits before Insul-ation." (Great laughter and applause.) But the sweet-voiced one said, "Don't be so bitter about it. He is a real man. He almost always goes to Europe in the summer, but this summer he said he would stay and talk to the Western Society." (Laughter.) I said, "It may be. You

greatly arouse my curiosity. I should really like to see if there is such a man. Does he ever go into Society? Does anybody know him?" I said, "There are other reasons why I think that he is not a man. Now, I once heard Mr. Edison say——" Then the sweet-voiced one broke in again: "If you heard Mr. Edison say anything, you should come down here and tell what it was, especially if it was about this man."

So I finally concluded that I would come and tell what Mr. Edison said. Now, that goes back a long way. When I was young—my angel infancy—my father's most intimate friend was George H. Babcock, the inventor of the B. & W. boiler. Mr. Babcock thought that the child might possibly make an engineer. He gave me some lettering and a little drawing to do, and it seemed to be not so bad as it might be, and he had hopes. As I look around on this audience and see brilliant men who were once in my own classes, and still lived through it, and see such men as my friend Professor Richards and Professor Talbot, and my colleague, Dean Woodworth, I think that they will agree with me that Mr. Babcock is not the only man in the world who has been mistaken—badly mistaken, about the capacity of boys to become engineers. (Laughter.)

Well, it was on the 14th day of July in the year 1880 that Mr. Babcock took my father and me on a trip down to Menlo Park. And at this point I see still plenty of Adam's ale around here, and I see little flashes of Madeira, and I guess a little claret, and I will give you a toast that is a toast, if you will rise to it: I give you "The Noblest American of Them All, Thomas Alva Edison!"

(The toast to Mr. Edison.)

Thank you.

Well, we went down there by the Pennsylvania Railroad, which stretched away straight across the meadows. And one of the first things my father asked Mr. Edison was how fast he would run his little electric train over that road if they would give him a chance. And Mr. Edison pulled one of his eyebrows—I don't remember which, and twisted the cigar in his mouth and said, "Well, I would be satisfied at 90 miles; but I asked them to let me try it and they wouldn't do it." Then he took us for a ride on his machine. The current went up one wheel—the axle was insulated—into the motor and out on the other side. The engineer sat on top of the engine. Mr. Edison and the rest of us sat in the car—Mr. Edison, Mr. Babcock my father, and I think a finely-whiskered young gentleman named Upson. Was there such a man?

Mr Insull: Upton.

Toastmaster Lewis: Upton, that was it. And Mr. Edison said only two things to the boy that day. He said them both with a twinkle in his eye. He said: "We ran her at forty miles yesterday and she jumped the track." (Laughter.) The other thing he said to me was in the room where he had a whole lot of Sprengel pumps that he had improved. He was testing out the electric light. And he said, "I have got a high-school teacher"—maybe it was a high-school principal—"in South America hunting for bamboo." That was no news to me. I had known high-school principals to hunt for bamboo many a time. And when it came to sending them to South America or Africa, I thought he might better have sent one of the boys, if he expected to get any (laughter).

I remember feeling that probably the train would win out, that we should have electric trains everywhere very soon, but I didn't know about that electric light, that probably never would be practical. But it was interesting to see Mr. Edison so enthusiastic about it—in his very quiet way, but still very enthusiastic.

Well, Mr. Babcock and he had a little talk about the boilers. Mr. Babcock was putting in boilers for him. That I did not understand, except there were constant references to a man, I think his name was Sims, who had been building or was going to build for him an engine that would run faster than any other engine in the world. We had a very, very good time.

And as we were going away, my father said to him—I remember his exact words; he did not say, "It is very wonderful, Mr. Edison." He said, "Mr. Edison, it is the wonder of wonders. It almost seems as if you had found the secret of life itself." And Mr. Edison, looking down as he almost always did, said, "Doctor, I am not sure but we have." And that is the last thing that I remember from Mr. Edison.

Now, why do I bring that in? The point is still—I am going to continue to prove to you that there is no such gentleman as the gentleman whose name appears here, for if Mr. Edison was right about it, the man is only an electrical machine. If you look at this so-called man closely, according to Mr. Edison's prescription of the year 1880, all you will see is a cloud of electrons. As you consider them more closely, you will see that each is very like the planet Saturn. You will find that each has a core impenetrable at present to classical mechanics, and a little ring of one or two or four electrons—valency electrons, or whatever they are called. You will find such things, but certainly not a man! And a cloud of electrons has no rights, patent or otherwise (laughter).

Well, some years after that a man in Brooklyn, a newspaper man, got hurt, and he had to take to writing special articles. He went to Mr. Edison and asked him his views on a large number of things. And Mr. Edison took pity on the lad and talked with him far more freely than he usually does. Among other things the boy asked him whether he believed in the future life. "No," said Mr. Edison, "of course not. Future life? I am not a person, I am only a colony of cells. When I cut my finger, the blood comes. It is the cells that bleed. When those cells are dissolved at my death, that is the end of me." Now, I submit to you, gentlemen, that if Mr. Edison was right, we have no person here tonight but only a distinguished British Colony of cells (laughter).

It is quite true that things happen in that colony. Under the brain-cap of this colony of cells, they tell me, there is a thin film of triangular cells with communication between centers. And I suppose that at this moment there is flashing between those centers a wonderful lacy midnight of orderly pale lightning of thought (great laughter).

I suppose that he has all the important cities of the world there as centers—Oak Park, Calcutta and Downer's Grove and Chicago (laughter) —he has got some sort of scheme by which he is going to get universal electrical supply cinched from here to Calcutta and back (laughter).

Well, about that little visit of ours in July, 1880. There was one other thing that I might have mentioned. I don't remember whether it was Mr. Upton or Mr. Babcock who made the remark—it was a passing remark. Mr. Edison pointed to the enormous cable above his head and said, "I am bringing it all over that, and I have got more now than I know how to attend to." And either Mr. Babcock or Mr. Upton said, "Perhaps you need a business manager." The following February Mr. Edison brought over from England a private secretary, who in time became his business manager. And, speaking after the manner of men—not speaking scientifically like Mr. Edison about electro-cellular organisms—speaking after the manner of men, every man here knows that that secretary became one of the most powerful and remarkable organizing intellects that this country has ever sheltered.

Now, I am to have the honor of introducing this colony of cells to you, this lacy midnight of orderly pale lightning (laughter). And it is up to him to prove to you that he is a man. I feel very certain that before he gets through you will find that he is not only a man, but a big man. Let us rise to him—Mr. Samuel Insull. (Great applause.)

(Mr. Insull's address will appear in a subsequent issue of the Journal.)

President Grant: In behalf of the Society I wish to thank Mr. Insull and Dean Lewis for their presence here tonight and assure them that we appreciated their efforts highly. Also, to thank the committee which had

charge of the arrangements for this evening, of which Mr. Keller was one of the active members.

I have refrained this evening from presenting any plans for the activities of the Society during the coming year, but that does not mean that there are no plans.

Anything involving new activities will first be presented to the Board of Direction.

The new Board will meet within a few days and as far as possible plan the work for the new year.

I feel very humble in standing here tonight before you fellow members. President Jackson informed me the other day that I had a man's job. Notwithstanding the eminent authority in the matter, I disagree with him. I think it is a job beyond any one man. It is a job for 1,228 members of the Western Society of Engineers plus the members we are going to add in the coming year.

This evening completes another successful year in the Society's history and as usual we have punctuated it by a good dinner. It is now up to us—and please note that I said us and not you or me—to face the new year with the firm and steadfast resolution to promote the Society's welfare at every opportunity. The opportunities will begin upon the adjournment of this meeting.

And the meeting is now adjourned.

Journal of the
Western Society of Engineers

Vol. XXI. FEBRUARY, 1916 No. 2

VENTILATION REQUIREMENTS AND TEST METHODS

By Dr. E. V. Hill*

Presented December 13, 1915.

Our ancestors did not live in steam heated apartments; they did not work in poorly ventilated offices, workshops or factories; and their children did not attend school in overheated, poorly ventilated class rooms, and consequently they were not afflicted, so far as we know, with tuberculosis or the foul air diseases so common at the present time.

They lived under what we usually speak of as natural conditions and by the operation of the law of natural selection developed a respiratory apparatus perfectly adapted for its work in the open air.

You should remember in this connection that the life history of the human race, since the dawn of civilization, is but a day in comparison with the many thousands of years man was undergoing the process of development from his ancestral type even to the stage of the most ignorant savage, consequently the respiratory apparatus which we are using today was developed in and for the open air, but our life at the present time, under modern conditions, is the direct opposite. We are in a confined space practically the entire time, from the home to the street car and then to the office or factory, as the case may be. We return from our work in the street car and attend a theatre in the evening for recreation and then back to our homes, spending only a small fraction of the twenty-four hours comprising the day in the open air.

The result of living under these unnatural conditions is the extreme prevalence of certain diseases called the foul air diseases, which take an annual toll in Chicago of something like 10,000 human lives. It is evident, therefore, that man must return to natural outdoor life or devise unnatural or artificial means to correct the bad results from his confined existence. This situation was more or less clearly understood a century ago. Heckle speaks of the high death rate from typhus among Napoleon's soldiers as being due to poor

*Department of Health, City of Chicago.

ventilation in their barracks and states that this disease caused more deaths than the bullets of the Allies.

Various experiments have been tried in the past to provide ventilation, with a view of correcting the above difficulty. Naturally the first experiment was with windows, and while they served the purpose admirably when a large air space per occupant was available it was soon found that in cold or inclement weather, where a large number of persons occupied a limited space, window ventilation was unsatisfactory and insufficient. Various types of ventilators and ventilating flues were experimented with and still have a limited field of application. But little actual progress was made until the invention of the centrifugal fan.

In 1847 Mr. Buckle presented before the Institution of Mechanical Engineers data for the design of a fan which does not differ greatly from those of the present time. From this to the modern multi-blade type is only a short step, and the improvement is probably only in an increase in efficiency of 10% or 15%. With this device, together with a suitable arrangement of distributing ducts, heaters, etc., a continuous and adequate air supply can be secured and controlled at a minimum of expense. This was the solution of the ventilating problem up to within comparatively recent years. Installations were made during this period on the assumption that if 30 cu. ft. of air per occupant were introduced into a school room or assembly hall and a constant temperature of 69 deg. or 70 deg. maintained, nothing more could be desired and the room was considered as being thoroughly, effectively and scientifically ventilated.

It soon became evident, however, that this so-called plenum system of ventilation was not altogether satisfactory. The air conditions, where rooms were ventilated in this manner, gave rise to severe criticism from teachers in schools, physicians in hospitals and similar institutions, even though the best of engineering skill in design and the constant operation of equipment was practiced. For example: The teacher in a school would complain (and still does) of poor ventilation. The man in charge of the heating plant would come up and look at the thermostat, see that the required temperature was being maintained and that the proper amount of air was being introduced and straightway conclude that the teacher had no cause for complaint.

In many hospitals mechanical equipments have been thrown out and window ventilation substituted. This unsatisfactory condition was largely responsible for the appearance of the natural ventilation faddist or open-window crank, who would rather have his fresh air through an open window than from any patented or mechanical device. We often see statements made by otherwise well informed individuals that so-called natural ventilation, by means of open windows, is much to be preferred to mechanical. Such phrases as "throw open the window and allow God's air to enter" are applied to the former method, and expressions like "canned air" are sometimes used to describe the latter. To those who have made

a study of this question these statements appear ridiculous. It is perfectly proper to laud natural ventilation by means of open windows, where this method is applicable, and it is also proper to condemn certain methods or individual mechanical installations, but to condemn mechanical ventilation *per se* is an indication that the person so speaking is not well acquainted with the broad requirements of air conditioning.

There was a case called to the attention of the Chicago Health Department some years ago that illustrates this attitude of mind. An old man lived on Sixty-third street with his two daughters in a frame building which he occupied by squatter's right. The premises were not supplied with gas, electricity or city water, and the old man dug a well in his back yard, about 40 ft. from a stable, to obtain the water supply for himself and family. Naturally the well was polluted by surface drainage from the vicinity. Samples of the water were analyzed by the department and pronounced unsafe. The old man objected strenuously to the department order to provide a city water supply for the premises and insisted on using the water from his well, stating that all of his ancestors back to the time of Jacob had secured their water supply in this manner and it was good enough for him. . . . After the funeral of himself and one of his daughters from typhoid the remaining member of the family filled up the well and installed modern sanitary plumbing appliances.

It is perfectly plain to sanitarians that the old natural method of obtaining water from a well or from a cool stream is not desirable under the present conditions of city life. The same can be said of our food supply. The natural methods used by our ancestors have long since been discarded. The natural method of living in trees or caves, as the case might be, cannot be defended at the present time. These facts are perfectly apparent and need not be insisted upon when talking to intelligent people who have given sanitary questions any consideration whatever. The reason is evident—the human race does not exist under so-called natural conditions and has not for several centuries past. The natural food supply, the natural water supply and the so-called natural air supply are not now to be obtained. Human ingenuity, therefore, has devised artificial or mechanical means to meet these artificial conditions. The water supply in Chicago, almost without exception, is mechanical; it is impossible to get a pure natural supply. The same can be said of the food supply except to a very limited extent; also to our habitations and places of employment.

The natural outdoor temperature must be increased in cold weather by means of artificial heat, and it is in this way that the human race has made regions comfortable which were previously uninhabitable. The question of an air supply has not been given the same study by sanitarians, and catchy phrases like "open the windows"—"God's fresh air," etc., meet a ready acceptance even though it is impractical or even impossible to obtain a clean and pure air supply in this manner. I do not wish to be understood as

condemning the free use of open windows where the desired results can be obtained from their use, but I do object to the preaching of natural ventilation where it is entirely impractical. It is an artificial condition where several hundred or thousand people congregate in a room where a temperature of possibly 50 deg. above the outside is maintained and it is foolish to speak of natural ventilation in a case of this kind. The only method of supplying air of the quality and quantity necessary for the health of the occupants must be by a mechanical system.

On the other hand, it is evident that the criticism of buildings mechanically ventilated in many instances are just and the demand for the use of windows, especially in school buildings, has a sound basis. The explanation appears to be that many of the important factors in the ventilation problem have been ignored or misunderstood and satisfactory results, therefore, not obtained. This condition has given rise in recent years to considerable investigation in various quarters, and while it is possible that we have not arrived at an ultimate solution of the problem, still enough work has been done and sufficient data collected from which to formulate ventilation requirements which, if enforced, will give satisfactory air conditions in our school rooms and assembly halls regardless of weather conditions outside.

I will not take the time to review all the work done by physiologists in recent years in an attempt to solve this problem, but will direct your attention to a few of the important results of their researches. The work of Leonard Hill and his associates brought out:

1st—The relatively innocuous nature of carbon dioxide in respired air.

2nd—The necessity for perceptible air movements in mechanically ventilated spaces.

3rd—That a high relative humidity, especially in connection with a high temperature, is responsible for much of the depressing effects in poorly ventilated rooms.

4th—The Chicago Commission on Ventilation in the experimental room of the Chicago Normal College, has conducted experiments which bring out the relation between the temperature and humidity in its bearings on comfort. The Comfort Zone Chart was plotted from 152 experiments with varying degrees of temperature and humidity in this room. (See Fig. 1.)

5th—Considerable data has been collected by the Division of Ventilation of the Chicago Health Department showing a rather constant relation between dust and bacteria in the air of theaters, schools and assembly halls where rooms are ventilated by the use of windows or with a mechanical equipment without an air washer. Probably the most valuable work of the Ventilation Division has been in devising instruments and standardizing tests and test methods in ventilation work. The importance of the CO_2 analysis as an indication of the air supply and distribution has been carefully worked out and is now quite universally followed. (See Fig. 2.)

6th—Work of the New York Commission on Ventilation which tends to show that the appetite of persons confined in rooms mechanically ventilated decreases with the air supply. The findings of this commission also bear out the assertion made recently by Professor Winslow that old standards as to air supply have not been changed by recent investigations, although different reasons are now given for the standards used.

7th—Observations from various sources, bringing into prominence the importance of odors as a factor in ventilation work.

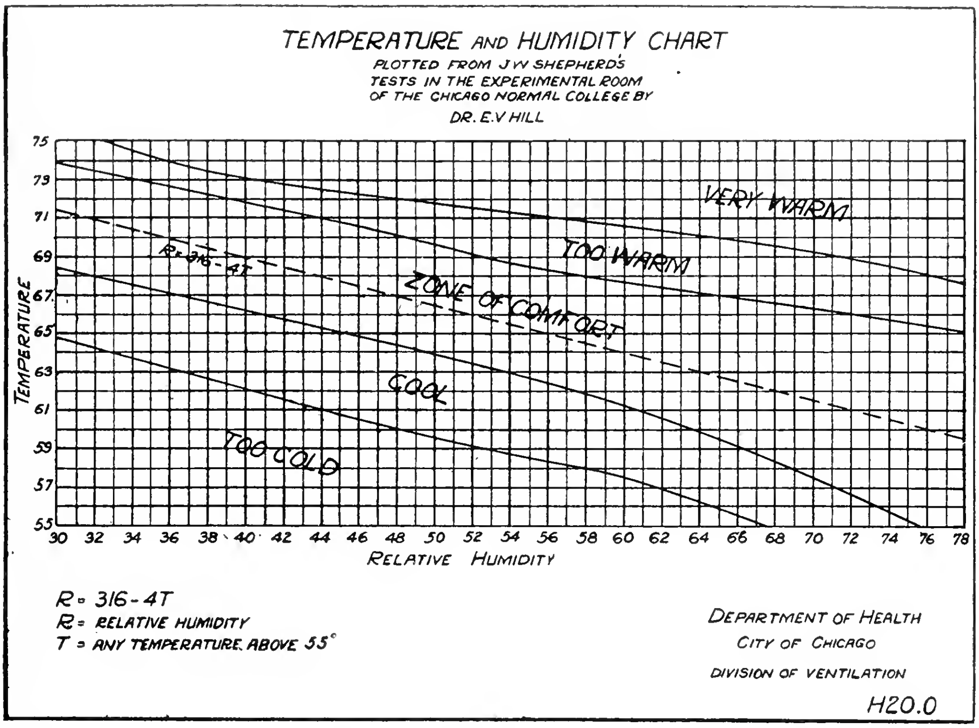


Fig. 1. Comfort Zone Chart, Showing Relation Between Temperature and Relative Humidity.

This research work in various quarters is still in progress. It has already given us a much better basis on which to formulate requirements. It also affords an explanation of many of the poor results noted from the operation of mechanical equipments in the past. From the information outlined let us now formulate requirements for good ventilation practice:

1st. Adequate Air Supply.

This will of necessity vary for different buildings and types of occupancy between 20 C. F. M. per person as a minimum and 30 C. F. M. as a maximum. It is extremely doubtful if, under ordinary conditions, proper ventilation standards can be maintained with less than this amount. It is also a question whether the expense incurred in providing more than the maximum specified is warranted. These standards are to apply where the air is obtained either by a natural

or mechanical system. Where air is re-circulated, washed and otherwise conditioned it is possible that the minimum of 20 cu. ft. per person can be somewhat reduced. However, as the expense incurred in additional equipment is considerable, and as it is still an open question whether any reduction, as stated, is compatible with the health of occupants of such rooms, this is a question that must be thoroughly studied and definite data accumulated before more can be said on the subject.

2nd. Comfortable Temperature.

This will depend again upon the nature of occupancy, it being from 60 deg. to 65 deg. where the occupants are actively employed;

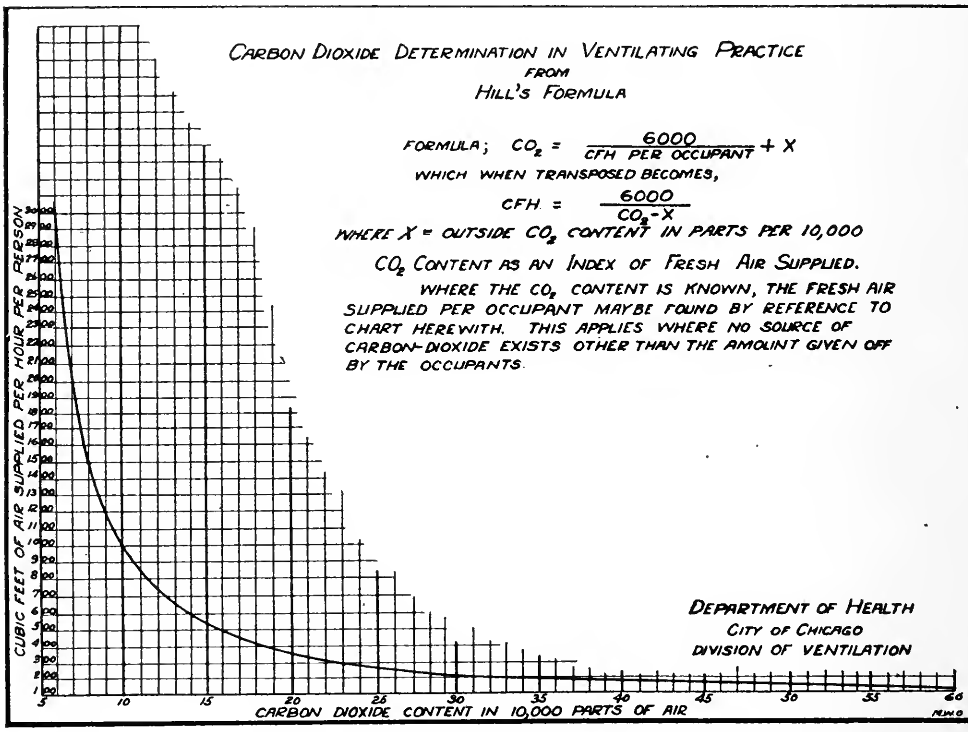


Fig. 2. CO_2 Chart, Showing C. F. H. to Maintain Any CO_2 Content.

68 deg. to 70 deg. when they are in repose. The humidity maintained also has a direct bearing on the temperature necessary for comfort.

3rd. Proper Humidity.

As intimated before, there is a percentage of humidity which is most comfortable for a given temperature. This humidity may be determined within the short range of indoor temperatures from the formula $R = 316 - 4T$, in which T is the temperature of the room and R the corresponding relative humidity. (See Fig. 1.)

4th. Perceptible Air Movement.

It has been shown by various investigators that the removal of the aerial envelope from the body is necessary if normal heat distri-

bution is to be maintained and individual comfort preserved. This is especially true when the percentage of humidity is high. The removal of this envelope is best accomplished by currents of air in the room which are just perceptible to the occupants. This air movement when the temperature is 68 deg. and the relative humidity 40% should be about 2 feet per second.

5th. Freedom from Drafts.

The mechanical ventilation of a room or even the ventilation by natural methods must be accomplished without the production of uncomfortable drafts. Air movement exceeding 2 feet per second is uncomfortable to some individuals, especially if the draft strikes the occupants from behind, if its temperature is lower than 68 deg. It is evident that drafts for a short period of time may be pleasant to one individual and objectionable to another, but continuous drafts over a period exceeding a few minutes cannot be maintained without serious consequences.

6th. Freedom from Dust and Other Impurities.

One of the essential requirements in ventilation work and one which has not been given the attention it should in the past is the purity of the air supply. Air purity in the past has meant, especially to the layman, freedom from the products of respiratory contamination. Impurities from this source probably are less important than most people think. On the other hand, dust contamination almost of any kind or source is a much more serious difficulty than is usually supposed. The conception is altogether too prevalent that all outdoor air is fresh and pure. This is far from true. The seriousness of the dust nuisance in cities has only recently been appreciated. The dust content of air samples even in clear weather, taken in Chicago, compared with those from rural districts or over Lake Michigan, revealed the fact that there is no time except directly after a heavy rain when the air is anything like what nature intended in purity. Daily counts were made of dust particles in the air from samples taken on the roof of the City Hall for 60 consecutive days during the autumn of 1914. While the counts within 12 hours after a heavy rain were fairly low, averaging from 15,000 to 20,000 particles per c.c., the average condition at other times was very unsatisfactory even at this height above the street. The counts increased in numbers from 15,000 after a rain to over 1,000,000 particles per c.c. during dry weather.

7th. The Minimum Number of Bacteria.

Under ordinary conditions a high dust count means a high bacterial count, and while the greater portion of these bacteria are of the so-called non-pathogenic variety it is becoming more and more evident that the inhalation of the non-pathogenic bacteria is not compatible with the best air conditions from the standpoint of health. (Fig. 3.)

8th. Freedom from Odors.

The importance of this factor can best be brought out by several illustrations. One instance that came to my attention was where a teacher in a school complained bitterly of the foul air in a certain class room. Upon investigation the following conditions were found: The air supply per pupil was 32 C. F. M.; dust count 15; colonies on a five-minute plate averaged 7; CO_2 7 parts. In spite of the apparently satisfactory conditions shown from the foregoing

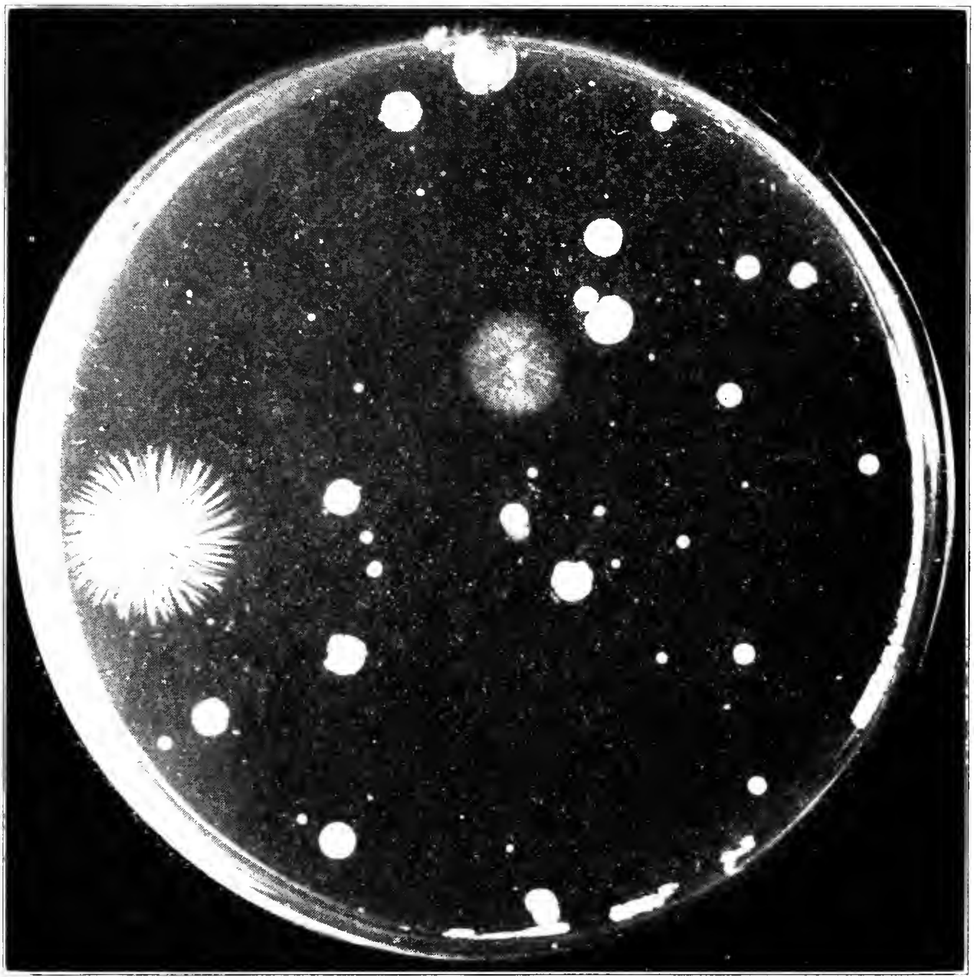


Fig. 3. Bacteria Culture Plate.

tests, there was an unmistakably bad primary sense impression. A careful examination was made of the region about the intake and the ducts in this room, without being able to locate anything that would throw light on the question. The information was finally gained from one of the pupils that a girl sitting in the seat opposite had lost her pet canary by death. She had laid out the remains in a thread box and kept the same in her desk until it was discovered.

The odor was so slight that it was almost impossible to recognize it as an olfactory impression, nevertheless it was sufficient to cause a definitely bad air impression in the room. Many instances of a similar nature might be recounted. One occurred in the City Hall recently where the head of a certain department complained of the foul condition of the air in his office. Repeated tests failed to disclose any difficulty with the air supply, until the rug, which was an expensive Oriental article, had been removed for cleaning. The bad air conditions were not noticed again until the rug was returned, when the complaints were renewed. In this way the offending article was detected.

You will see from the foregoing that the problem of ventilating an enclosed occupied space contains many variable factors. Simply supplying a certain amount of air and maintaining a certain temperature is not sufficient. We must have in mind all of the various factors previously discussed when testing an equipment and most of them when designing the same.

I will now call your attention briefly to some of the important features in correct design and then describe the methods used in testing the completed installation. There are at least ten features in mechanical design that should be considered by the engineer when laying out his work; they are:

1st—Proper location of the fresh air intake.
2nd—Temperature control.
3rd—Elimination of dust and other impurities.
4th—Humidification and de-humidification.
5th—Air distribution.
6th—Accessibility of all parts of the equipment for cleaning.
7th—Pressure requirements.
8th—Accurate duct design.
9th—Relation of design to installation.
10th—Relation of design to economical operation.

1st. The Proper Location of Intake.

It has been repeatedly demonstrated that where an intake is located in a sidewalk, bulkhead, window or other low point close to traffic, or even at points as high as 10 feet above grade, contamination of the air supply with dust and dirt is very large even though an air washer is used, for it is a well-known fact that the efficiency of air washers in dust removal varies from the maximum of 95% or 96% under favorable conditions to as low as 10% or 15% under unfavorable conditions.

2nd. Temperature Control.

Heat control, preferably by thermostatic means, is almost imperative in auditoriums or class rooms. This is not because the temperature in the room must of necessity be maintained at a fixed point, but to prevent subjecting the occupants to cold drafts of air. A floor introduction plant may be perfectly satisfactory when the

air is being brought in at 68 deg., but would be extremely unfavorable supplying the same amount of air if the temperature falls to 64 deg. or 65 deg. This illustrates the necessity of accurate temperature control where the occupants of a room must of necessity be close to the supply registers.

3rd. Elimination of Dust and Other Impurities.

The fact that dust is something more than a mere inconvenience, as was formerly supposed; the fact also that it gives rise to objectionable odors or deleterious substances when decomposed by the heaters, makes it plain that air washers or other means of dust removal must come into universal use in city work.

4th. Humidification and De-humidification.

We have spoken of the desirability of a proper amount of moisture in the air only from the standpoint of comfort. While this is important, it is more important from the standpoint of health that we realize fully the bad effects of the low humidities maintained in cold weather, and also of the depressing effects in high humidities in moderate weather. It is perfectly apparent that every school building should be supplied with an efficient air washer and humidifier and devices for automatic humidity control in cold weather.

5th. Distribution.

Much has been said in recent years regarding the distribution of air, but little has actually been done. Much discussion has prevailed regarding the comparative value of upward as against downward ventilation. I feel strongly that there is no room for an argument of this kind; in fact, there is no room for arguments regarding methods of air distribution at all. Every problem should receive individual attention regarding the means and methods employed, taking into consideration exposed walls and windows, the temperature of the entering air, the configuration of the room or building and the various other factors that bear directly on the problem.

6th. Cleanliness of Air Ducts and Equipment.

This phase of ventilation work is one that has never been given even passing notice, so far as I am aware. We find that in practically every ventilating job installed no consideration has been given to the cleaning of the ducts, and in some instances to coils, fans, etc., after the original installation. I can point to several schools in Chicago where an accumulation of carbon, grease and other impurities in the fresh air ducts is so extensive that they look and smell like the inside of an old chimney. In one installation, where complaints from the teachers were persistent, this was the only difficulty and a thorough cleaning with an alkaline solution and a hose remedied the objectionable odors which were not even recognized as such but which were the sole cause of the poor results obtained. There should be no part of the fresh air supply of a mechanical equipment that is not accessible for thorough cleaning at least once a year.

7th. Pressure Requirements.

Considerable discussion and some ill-feeling has resulted from the rule which is more or less universally followed in school buildings throughout the country. I refer to the requirement that windows be kept closed in school buildings during occupancy, on the assumption that opening them unbalances the ventilating equipment. While this is true in many cases, it is a situation that should not obtain and one for which there is no excuse. Without entering into a discussion at this time of the merits or demerits of opening windows in class rooms, it must be conceded there is serious objection to a rule forbidding the practice. The psychic effect is bad if one is forbidden to open a window and conversely there is a certain value from the same standpoint if further use of windows is allowed when weather conditions permit. There is no excuse for the design or installation of a mechanical equipment in a school building that does not allow of the full use of windows. It is only necessary to carry a low velocity and a high static pressure in the mains, throttling either at the throat of the branches or at the outlet registers, so that the difference in pressure between the main and the room is considerable, to nullify the effect of opening any of the windows in a building. This is a matter that should be brought to the attention of designing engineers in school work.

8th. Accurate Duct Design.

Another practice which is prevalent but which should be discontinued is the haphazard method of designing ducts to carry certain air volumes, irrespective of the static resistance in the same. It is much easier to guess at the size of the ducts required and to control the air volume by means of splits and dampers than to design each branch with the view of making the static resistance control its air supply; however, the air split method is extremely unsatisfactory. Proper adjustment is extremely difficult and when one damper gets out of adjustment the whole system is disarranged. If the equipment is properly designed without air splits or dampers, it cannot become disarranged or out of adjustment and much better results will follow.

9th. Careful Installation.

It is not a difficult matter for the engineer to properly design the entire equipment, even to the minutest detail, but it is too often the case that the superintendency of installations is left to some person who does not realize the difference made in an improper turn or a poorly constructed duct. This is one of the principal reasons why air splits and dampers are so often resorted to. It is apparent, however, that if heating and ventilating engineers would meet and overcome the objections and complaints arising from improper operation of mechanical equipments they must see to it that the installation is made in accordance with the design.

10th. Economical Operation.

This is important in all cases, especially so in small plants where the necessity for mechanical ventilation is not fully appreciated.

The last part of my talk this evening has to do with a phase of ventilation work that has been neglected to a certain extent in the past. This is the testing of the completed equipment to see that the desired ends have been obtained. It also has to do with the testing of air conditions where the supply comes from the open window or any other source. This side of the ventilation problem is of extreme importance. The physician and surgeon in the past has acquired knowledge and skill from one particular field more than from any other, this is from the post mortem room. It is usually only by following his case to the post mortem table that he learns to correct mistakes in diagnosis and treatment. The complete and accurate testing of a mechanical ventilating equipment is frequently a good comparison to the post mortem of the physician. While all installations should not be included in the comparison, a large percentage may be. If the engineer could follow in tests the plans he has designed much of the recent criticism of mechanical ventilation would not occur. I will divide methods of testing into five subheads, as follows:

(a) *Air Velocities.*
 1st—Anemometer.
 2nd—Pitot Tube and Gauge.
(b) *Air Movement.*
 1st—Ammonium-Chloride Test.
 2nd—Phenol Phthalen Test.
 3rd—Balloon Test.
(c) *Air Analyses.*
 1st—Taking Samples.
 2nd—Analyzing Samples.
(d) *Bacteria.*
 1st—Culture Methods.
(e) *Dust.*
 1st—Aitken Portable Dust Counter.

By means of these test methods we determine to what extent the requirements for proper air conditions previously discussed are accomplished in installations being tested.

1st. Anemometer.

The anemometer consists of a small wheel carrying eight (8) vanes. The wheel is connected by suitable gearing to indicating hands on the dial and the instrument is so calibrated that the revolutions of the vanes indicate the velocity of air passing through the instrument in feet per unit of time. The wide divergence in the readings obtained by two persons with the same anemometer, under the same conditions, should not be attributed to inaccuracy of the instrument, but rather to ignorance or carelessness in its use.

The first requisite is that the instrument be in good repair and properly calibrated. The second is that the readings be accurately timed. The third is that the proper method of taking readings be employed.

In taking readings at the register face the method of slowly moving the anemometer across the register or up and down, as the case may be, is only mentioned to be condemned. The reading will be inaccurate except at those registers where the velocity is uniform throughout the entire area. In taking readings where the velocity varies over different areas of the register face, it can readily be seen that in moving the instrument slowly across the face of the register the momentum acquired by the revolving vane over the areas of high velocity will cause it to continue to revolve at a much higher rate than it should while passing over the areas of low velocity, consequently a much higher average velocity reading will be obtained than the conditions warrant. The proper method is to divide the face of the register into equal areas of approximately 6 inches, and take one-half or one-minute readings at the center of each square. The average of the total number of readings times the area of the opening will give the cubic feet of air delivered. (Fig. 4.)

2nd. Pitot Tube and Gauge.

The velocity of air flowing through a given duct depends on the difference in pressure maintained between the entrance and outlet. It is necessary to consider this pressure as made up of two components: (1) that which is required to compensate or overcome the loss due to compression and frictional resistance (static pressure); (2) that which is necessary to move the volume of air at the given velocity (velocity pressure). The sum of the two is the total or dynamic pressure. The air velocity is determined from the formula $v=\sqrt{2gh}$, which transferred into terms of air becomes $v=1096.5\sqrt{\frac{P}{W}}$ where v is the velocity in feet per minute, P is the velocity pressure in inches of water, and W is the weight of one cubic foot of air at the given temperature.

As there is no way of determining the velocity pressure directly, the total and static pressures must be determined and the latter subtracted from the former to obtain the velocity pressure. For making these determinations the Pitot tube is the most satisfactory instrument from the standpoint of accuracy and convenience. The tube shown is of the American Blower type, 48 in. long, with a tip 4½ in. long. The static openings are four in number, two on each side, and .02 in. in diameter. The static branch of the tube is on the forward or tip side and the total pressure branch at the rear. (Fig. 5.)

The readings are taken on an Ellison draft gauge provided with a special head and leveling device to be used in connection with a

tripod. This makes a portable and very convenient apparatus. (Fig. 6.)

3rd. Ammonium-Chloride Test.

When strong ammonium hydroxide and hydrochloric acid are volatilized and the two gases brought into contact a chemical reaction results with the production of ammonium chloride. This am-

Fig. 4. Taking Anemometer Reading.

monium chloride occurs in a very finely subdivided state, is distinctly visible as a white cloud, and does not readily settle out of the air. This is a valuable method for studying the direction and velocity of the air currents in a room.

The apparatus consists of two 25 c.c. bottles carried in a small leather case, one containing the acid and the other the ammonium hydroxide. By means of a small rubber force pump air is bubbled through the two bottles and the volatilized products brought together

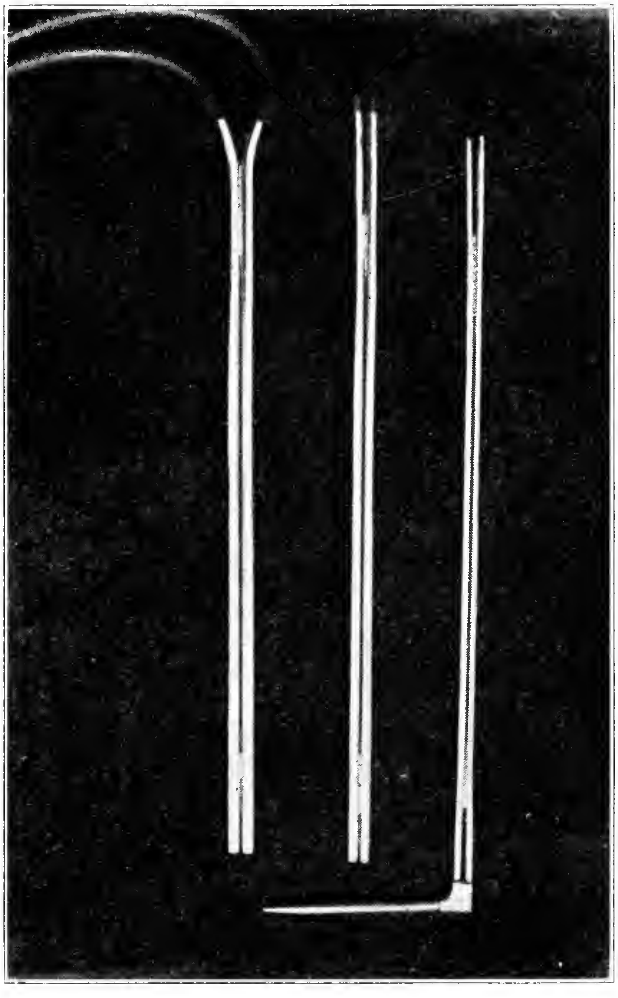


Fig. 5. Pitot Tube Used with Draft Gauge.

at the nozzles of the tubes projecting from each. In this way the cloud of ammonium chloride is produced conveniently in any location and its action observed. For determining the velocity of the air movements in a room a puff of the smoke is produced and its direction noted. The second observer then stations himself 10 ft. away, in the line of the air motion, from the one holding the apparatus. A puff of the smoke is now liberated and by means of a stop watch the second observer notes the time the cloud reaches his station.

4th. Phenol Phthalen Test.

This test depends upon the reaction which occurs in a weak alcoholic solution of phenol phthalen when acted upon by a strong alkaline reagent. As this test is rather difficult to illustrate except with an elaborated stage setting, I will not attempt to do so this evening, but refer you for a complete description of the same to the report of the Chicago Commission on Ventilation.

5th. Balloon Test.

Small toy balloons are inflated with hydrogen gas and counterpoised with small improvised weights. These weights are just sufficient to keep the balloons in the air at the temperature of the room. They are liberated at various points and give a very interesting visual demonstration of air currents.

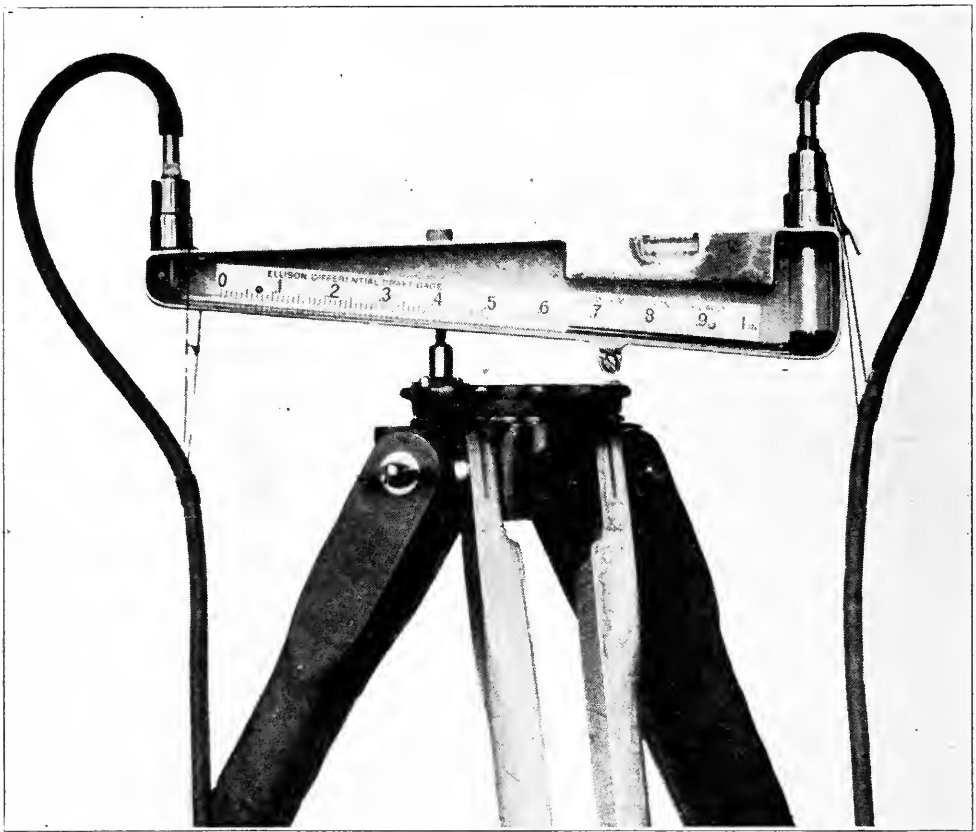


Fig. 6. Draft Gauge Mounted on Tripod.

6th. Air Samples.

The apparatus for taking air samples, to determine the carbon dioxide content, consists of clean rubber stoppered bottles holding about 120 c.c. each, a Paquelin cautery bulb and 24 inches of tubing. The apparatus is held at arm's length from the body, great care being exercised that the expired air from the observer's mouth does

not contaminate the sample. The cork is removed and the tube inserted to the bottom of the bottle. The tube is closed by pressing it between the thumb and the neck of the bottle and the bulb is compressed until the reservoir is distended. The thumb pressure is then released and the air in the reservoir allowed to rush into the bottles, displacing the residual air. This operation is repeated three times in order to be sure that all of the air originally in the bottle and apparatus has been replaced by the air to be sampled. I will

Fig. 7. Taking Air Sample.

have my assistant take several samples throughout the room and notify you later as to the results. (Fig. 7.)

7th. Analyses of Samples.

Analyses are made for carbon dioxide with a modified Peterson-Palmquist apparatus.

Regarding the analysis for carbon dioxide in ventilation work, I would like to call your attention to the following: The prevalent

opinion in the past, especially among the laity, has been that carbon dioxide, being the product of respiration, is necessarily injurious; in fact, it has been considered by some as the most injurious substance in vitiated air. This theory was discarded 60 years ago and Pettenkoffer called the attention of the medical profession to the fact that its use was only valuable as an indication of other respiratory impurities. We use it at the present time only as an indication of the amount of fresh air supply and for no other purpose. Knowing the average amount of carbon dioxide exhaled by the audience, and knowing also, or determining by test the amount in the outside air, it is a simple mathematical calculation to determine from the average CO_2 analysis in a room the fresh air being supplied. This is valuable to check on, supply and distribution, where a mechanical equipment is being tested and it is extremely valuable in determining the amount of air supply in an auditorium, room or other occupied space where the air supply is obtained solely through natural means. The formula and chart used for this purpose is shown in Fig. 2.

8th. Bacteria—Culture Method.

Cultures for the determination of bacteria are made by exposing Agar plates for a period of three minutes. These culture plates are then placed in an incubator for 48 hours at room temperature and the colonies that develop are counted. I will have my assistant make plates in various parts of the room and notify you later as to the results obtained after the reports from the laboratory are received.

9th. Dust.

The determination of dust in the air is a matter that is being given more attention than ever before. We have experimented with various methods, and while none of them is entirely satisfactory, the Aitken portable dust machine has given us the best and most consistent results up to the present time. The machine consists of a chamber lined with hygroscopic material; a filter for obtaining clean air; a measuring device and a rule objective for counting the dust particles obtained. The principle on which this apparatus works is as follows: The air from the room is drawn through the filter into the chamber until the latter is filled with air free from dust. A slight vacuum is now produced in the chamber by means of the pump and then a measured quantity of the dusty air to be sampled introduced. This is mixed in the chamber thoroughly and a further reduction in the pressure caused. This lowers the dew point and causes each dust particle to act as a nucleus for the condensation of moisture which falls in a fine shower of rain on the observation plate at the base of the chamber, when it may be counted by means of the magnifying eye piece. A modification of this method, suggested by Mr. Hoskins, has been adopted with exceedingly gratifying results. It consists of a smoked disc of glass or cover slip, as it is called, being introduced into the chamber and the

dust particles precipitated on the inside on the observation plate just referred to. These cover slips may then be removed and counted at leisure. In this way a permanent record of tests may be kept. (See photo-micrograph, Fig. 8.)

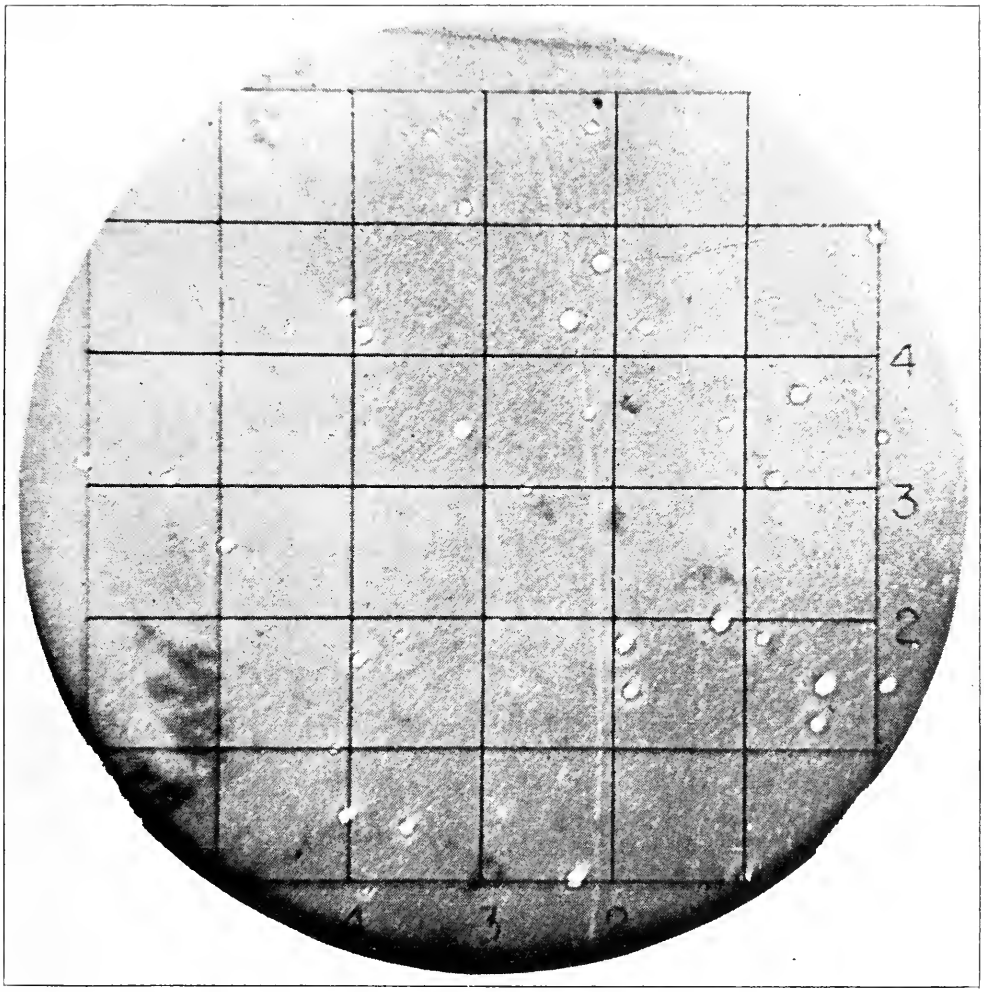


Fig. 8. Microphotograph of Dust Sample from Aitken Dust Counter.

The following is the laboratory report of tests made in the assembly room during the lecture:

Air samples analyzed for CO_2:

East aisle	6.6
Center aisle	7
Center aisle	7
Average	6.8 plus

Bacteria Cultures:

Platform	1	colony
Platform	1	colony
Center aisle	4	colonies
Average	2.5	

C. F. M. exhausted by fan	2700
Number of people in room	200

Remarks: The average CO_2 analysis for the room is 6.8, which, by referring to the carbon dioxide chart, gives an air supply of 2100 C. F. H. per person. The test of air exhausted by the mechanical equipment in this room was 2715 C. F. M., or a little over 1300 C. F. H. per person. It is evident, therefore, that the amount of air supplied to the room, according to the CO_2 analysis, is much greater than the amount exhausted by the mechanical equipment. By recalling the conditions in the room at the time of test, it will be remembered that the side doors, and also the entrance doors from the corridor, were open and that a very decided air movement occurred through the room irrespective of the operation of the exhaust fan in question, so you see that the results of the CO_2 analysis verify this condition.

The culture counts average 2.5, which is very low. A count not exceeding 12 on a three-minute plate is considered satisfactory. The air movement averaged 3 plus per second, which is somewhat high but not uncomfortable in a male audience, especially when smoking is permitted.

The temperature averaged 72 deg. plus, with a humidity of 36%. You will note from the Comfort Zone Chart that this falls within the prescribed limits. An analysis of the total air tests conducted in this room show remarkably good conditions, especially when we consider the nature of the mechanical equipment in use.

Discussion.

C. P. Barnes: I was interested in an article describing some tests, I think by Professor Whipple of Harvard University, on the rewashing of air so that it could be re-circulated. I would like to have Dr. Hill's opinion on that.

Dr. Hill: The question of re-circulating air is one that is occupying a great deal of attention at the present time. It is apparent from tests we have made that from 85% to 92% or 93% of the dust and bacteria can be removed from the air by an efficient washer. Just what this means is for the future to determine. It is apparent that Professor Whipple leans somewhat toward the opinion that air can be re-circulated, if possible through a washer, without bad results. I feel, however, that it is wrong to take a position of this kind with the insufficient data at hand. It is, however, probable that a

part of the air used in ventilating public buildings can be re-circulated without any bad effects.

J. W. Shepherd: As I understand it, the work of Professor Whipple is along the general line of restricting the supply of fresh air—an investigation beginning a few years ago at Springfield, Mass. (in the Y. M. C. A. building), and later repeated in a public school at Minneapolis, and also more recently at the University of Wisconsin.

Dr. Hill referred to one of the recent conclusions which the New York Commission on Ventilation has reached, that upon whether or not appetite makes any difference to one's health. In a specially equipped room in the College of the City of New York, the New York Commission on Ventilation made a study of some students under identically similar working conditions, except that in some tests they had this "God's outdoor fresh air" referred to and in others they had re-circulated air. The test showed those who took the re-circulated air did not have the appetite and did not consume the food as did those who had the outdoor air. They are confirming that in some tests made in the New York schools, and some of us are inclined, perhaps, to carry the analogy that there is a connection between a man's appetite and his health. There is not enough definite information to determine whether or not we can get along with a smaller quantity of air than we have been heretofore getting. I lean in the direction of a larger volume of air. I think there is no such thing as getting too much, by which I do not mean to make a man bankrupt in order to get it, but I do mean that, other things being equal, I will take my chances with a larger volume of fresh air than a smaller one. The economic point at issue, of course, is the matter of cost.

I think everybody has given up the notion that we are about to find some organic or elusive thing in the air that is so very vital to life, but the recent work in New York seems to show that there is something in favor, at least, of an individual having a better appetite if he has more fresh air.

Albert Scheible, M. W. S. E.: Mr. Chairman—I have three questions I would like to ask:

First: Does the inspector of theater ventilation duly consider the paths traversed by the required supply of air? As I understand it, our city regulation as to the volume of air per person that is to be supplied in theaters or the like is in cubic feet per person, without definitely stating where that air is to be supplied. Now, as long as our respiration is largely concerned with the mouth and nose, it would seem as if a thousand cubic feet of air traveling across our knees or five feet overhead would not have the same effect as a thousand feet supplied at the height of our head.

Second: As to the effect of odors, pleasant as well as unpleasant. As I understand it, unpleasant odors are particularly objectionable in that they produce a reflex action on our respiration tending to check the deep breathing. It has always seemed to me

that part of the fad for open windows was due to the fact that we get a stimulus to deep breathing when we leave the stupefying air of a room and go into the fresh air. Now, if the objectionable odors deter the deep breathing, can we get the reverse effect by pleasing odors or by the use of ozone, as is claimed by some of the manufacturers of ozone making apparatus?

And, third: Is there any practical humidifying apparatus for use in the ordinary apartment house or dwelling house that is not unsightly in appearance?

Dr. Hill: In regard to the first question, which has to do with the points of entrance and exit of air in mechanically ventilated buildings, I will say that the ordinance requires a certain number of cubic feet per person per hour, and also specifies that the carbon dioxide content of the room shall not exceed 12 parts in each 10,000 parts of air in old buildings (that is, buildings constructed prior to the passage of the ordinance), and 10 parts of carbon dioxide in new buildings (that is, buildings constructed subsequent to the passage of the ordinance).

The reason for the carbon dioxide provision is apparent. If the carbon dioxide content does not exceed, we will say, 10 parts in any location throughout the room in question it is evident that the amount of air supplied at this point will not be less than 1000 C. F. H. per person. This is easily determined from the chart shown on page 94. The cubic foot of air per minute provision takes care of the total air supply and the CO_2 content its distribution.

With regard to the question of the method of introducing and removing air in mechanically ventilated buildings, I would say that various engineers have various views regarding the same. As a general proposition, if the air is introduced near the ceiling line it should be removed at or near the floor line, and conversely, if it is introduced at or near the floor line it should be removed at or near the ceiling line. In our tests of theaters and schools we have secured the best results where the air is introduced from the side walls 7 ft. to 10 ft. above the floor and removed at the floor line. It is true that where expense is not a serious consideration and where a sufficient number of registers are used to obtain a low velocity the floor introduction method gives very satisfactory results. It is necessary, however, to use thermostatic control with this method if complaints are to be entirely eliminated. Sometimes in banquet rooms and places of that character, where smoking is allowed, the air is introduced from the side walls 7 ft or 8 ft. above the floor and removed at the ceiling line. In this way the smoke is immediately carried upward and does not contaminate the breathing zone.

It is true, I believe, that most of the beneficial effects of cold air or the momentary cold draft is to stimulate deep breathing. I do not believe that this applies with regard to odors. Experience has amply demonstrated that the best air for breathing purposes should be odorless. Perfumes of various kinds have been tried in theater

ventilation with the idea that the audience would be pleased with the result. This, however, is not the case. Any perfume, no matter how pleasing to the olfactory sense, becomes objectionable in a very short time. No perfumes have been invented, as far as I am aware, that you can inhale continuously with gratifying results; they are pleasant for a short time only.

The third question, the one regarding humidification, I have some hesitancy in answering. There are several humidifying devices on the market, but we have not made sufficient investigations with regard to them to state whether or not they are practical and efficient. We know that it is highly desirable to humidify the air in cold weather—there is no question about that; I am not, however, in a position to recommend any humidifying device at the present time. It is probable that in the next year there will be a large number of these placed on the market, and we will be in a better position to know what they will actually accomplish.

Regarding ozone, that again is a question on which there is considerable diversity of opinion. I received two letters yesterday and one today, asking for information about a certain type of ozone machine. The manufacturers claim that it prevents pneumonia, sleeplessness, house maid's knee and many other ailments that I have forgotten, if used in the living rooms of dwellings. It is evident that most of these claims are entirely without foundation. The work of Hill and Flack in England demonstrated quite conclusively, I think, that ozone in concentration much above one part in 1,000,000 is decidedly irritating and injurious if one is subjected to its influence for any great length of time. It will mask certain odors and it will destroy certain other odors; it will mask some odors that will return after the ozone is cut off and destroy certain odors that do not return. Outside of its effectiveness as a deodorant we know of no beneficial results from its use; this, however, is of considerable importance and its value should not be underestimated.

C. W. Naylor, M. W. S. E.: I am with a big commercial house in the business district of Chicago. The question was asked as to circulating air over and over again. Along with that I will ask the advisability of circulating the wash water over and over again. We do so, running it from the fans in the wash chamber to a well or tank or reservoir holding perhaps a thousand gallons of water. It is pumped over and over again. Primarily, that is done for economy in order not to waste large volumes of city water at so much per thousand gallons during the entire twenty-four hours. In this tank is stored about a thousand gallons of water for the ordinary spray washing of air. After a period of a month, we sometimes take out at least a wheelbarrow of dirt or mud—dust originally, but mud when it gets in this tank. The water is taken from the center of the tank and is not always clear, but it is used over and over again for washing.

I wonder if Dr. Hill has given the subject thought enough to

state whether such practice is proper, or if it should be prohibited by ordinance or otherwise?

W. E. Williams, M. W. S. E.: I would like to ask what sort of washing you do with that water?

Mr. Naylor: We wash the air. In other words, the air is blown or drawn through a continuous spray of water pumped in under sufficient pressure to make it spray. The water falls and takes with it the dust, which is evidenced by the amount of dirt that we get from the reservoir periodically.

Dr. Hill: Mr. Naylor's discussion calls to mind an incident that is rather amusing. A system of ventilation which included a very efficient air washer was installed in a certain large bakery in this city a short time ago. The equipment had only been in operation a few weeks when the owner came to my office and wanted an inspector sent out to examine the air washer. He stated that there was something radically wrong with the device, as the water tank was filling up with mud and he could not see where it came from. Of course, the presence of the mud in the water tank was an indication both of the necessity for an air washer and of its effective operation. The extent to which the wash water can be re-circulated depends, of course, upon the amount of dust in the air passing through the machine. While the washer is in operation I do not believe that any of the dirt held in suspension in the water will be transferred to the air. In some of our tests we have noted that when the water becomes extremely dirty and the washer is shut down we find that after the water has evaporated from the eliminating plates a coating of dirt remains. In starting the apparatus some of this dirt is carried into the fan inlet; this is especially true if the fan is started before the washer.

H. P. Weaver, ASSOC. W. S. E.: A large proportion of our waking hours is spent in an office. I am thinking of my own case where I am bounded by partitions enclosing a space fifteen feet square and the means available for me to control the conditions in that room are radiators and windows. There is no means of humidification, and no means of controlling the sort of air that I get. I can do something at home with water pans and things of that sort, but I can not conveniently do so in the office. Has any thought been given to the large number of people that work in office buildings where they are little affected by artificial ventilation as applied to an office building as a whole?

Dr. Hill: There are several humidifying devices on the market that are arranged to replace the air valve on a steam radiator. I believe some of them are quite efficient, but it is a new field and these devices have not been very thoroughly advertised and little is really known as to their efficiency. It is perfectly practical, it seems to me, to get any desired humidity in a steam heated office by this method. I might say with reference to humidifying with a furnace heating plant, that this has been worked out with quite good results. A properly located pan in the furnace supplied with water, the

amount of which is controlled by an automatic float valve, and with some means of increasing evaporation in the pan, such as wicks, bricks or other porous material, gives all the moisture that is desired. These devices are manufactured by several concerns and have been on the market for some time.

Mr. Williams: The figures on the chart seem to indicate that a landlord who has a large building to keep warm might save in his coal bills by humidifying the air. Has that been gone into sufficiently to indicate just what saving might be effected?

Dr. Hill: Yes, it is true that you can maintain a lower temperature with a correspondingly higher relative humidity, but it requires just as much coal or just as many heat units to evaporate the water as it does to maintain the higher temperature, so there is practically no saving in the heat required. The saving is in the health of the occupants and not in the coal pile.

J. W. Lowell, Jr., ASSOC. W. S. E.: I would like to ask Dr. Hill if he has had any experience with electricity for washing the air or removing the dust. I do not know that it would be applicable to the ordinary room, but some experiments have been tried with air around some cement plants.

Dr. Hill: There is some experimental work going on along the lines mentioned by Mr. Lowell at the present time. Nothing has been developed so far that is of practical benefit in ventilation work. The discharge of a current of high potential between contacts has been used, I believe, in dispelling fog, but in dust removal I know of nothing that has been developed of commercial value.

Hyman Eli Goldberg, M. W. S. E.: I have many times in my home felt uncomfortable because of the steam heat and I was always told that we did not have sufficient humidity. Is there any simple way of telling the humidity?

Dr. Hill: The only way of determining the humidity is by the use of the wet and dry bulb thermometer. There are some devices on the market which are used for approximating the relative humidity; but they are far from accurate. I have one in mind, a post card with the picture of a little Dutch girl whose skirt is painted with a solution of cobalt. When the amount of moisture rises above a certain percentage the dress becomes pink and when the humidity goes down the dress becomes blue. The wet and dry bulb thermometer may be purchased anywhere from 60 cents up, and determinations made without any difficulty. This is the most satisfactory method and quite accurate. You will be surprised sometimes when the humidity is down around 15% or 18% at the feeling of comfort that results if you increase it. In summer or certain other times in the year when the humidity is high it is difficult to do anything to help the situation, but you can at least know to what your discomfort is due.

A. L. Wallace, ASSOC. W. S. E.: Considerable has been said about the removal or purifying of air in rooms where the air is considered near the floor; but very little has been said about the air

in foundries or industrial plants where considerable dust has been stirred up. I would like to have Dr. Hill give us a little information on the requirements in removing dust and dirt from rooms in foundries.

Dr. Hill: I do not feel that I can discuss that subject extemporaneously. It is apparent that the dust in foundries and some other manufacturing plants is injurious if inhaled. I might say this, that there has been in the past a prevailing opinion that a little dust is not necessarily injurious and that it can be inhaled with impunity; it has been considered more in the light of a nuisance or inconvenience rather than a menace to health. This, however, is not the case. Investigations along these lines are bringing the realization to us that the dust nuisance is much more than an inconvenience; that the inhalation of dust-laden air eventually has serious results.

Albert Scheible, M. W. S. E. (By letter): In the absence of confirmatory data, Dr. Hill's statement that the humidifying of the air will mean no saving in fuel does not seem plausible to me. The evaporation of the moisture needed for this humidifying, and the further heating of the steam to the temperature at which it is supplied, all require an expenditure of fuel. However, the dissipating of the resulting vapor in the air of the room and the absorption of its moisture content by the air without condensation would imply that the heat stored in the steam used for the humidifying was transferred to the air and hence utilized in heating the room. Even a comparatively small saving in fuel would constitute an effective reason for inducing the owners of buildings to provide humidifiers, hence I hope that Dr. Hill will continue his tests so as to include comparisons of fuel consumption.

DEFLECTION OF TRUSSES

By E. H. Casper, M. W. S. E., and C. J. Kennedy, Assoc. W. S. E.

Presented November 29, 1915.

DEFLECTION FORMULAE

CASE I. Truss under single load.

Let W = Single Load on Truss.

S = Stress in any truss member due to load "W"

L = Length of member in inches

A = Area of member in square inches. {Gross Area generally used for all members

E = Modulus of Elasticity = 29,000,000 for Structural Steel

Δ = Deflection under load "W"

Then $\Delta = \frac{1}{WE} \sum \frac{S^2 L}{A}$.

CASE II. Truss under any number of loads.

Let S = Stress in any member due to all loads on the truss.

A = Area of member as above

P = Unit stress in member $= \frac{S}{A}$

Q = Any part of load at point at which deflection is to be found (Usually taken as 1#)

U = Stress in any member due to Q

L = Length of member in inches

E = Modulus of Elasticity as above

Δ = Deflection at any point

λ = Change in length of any member

Then $\lambda = \frac{PL}{E}$

and $\Delta = \sum \frac{PUL}{QE}$

But where $Q = 1^{\#}$

$$\Delta = \sum \frac{PUL}{E}$$

CASE III- Deflection due to Temperature Changes

Let Y = Coefficient of Expansion = .0000067 for medium steel

T = Change of Temperature of any member in degrees Fahrenheit.

L = Length of member in inches

U = As noted above

Δ = Deflection at any point

z = Change in length of any member

Then $z = YTL$.

and $\Delta = \sum YTL \cdot U$

NOTES.

The derivation of the above formulae is very clearly discussed in "Merriman and Jacoby, Part I, Chapter VII," and "Johnson Bryan and Turneaure, Part I, Chapter VII," and other similar

books, and will not be further considered in this paper, as it is with the application, rather than the derivation, of these formulae, that this paper deals.

The preceding formulae, and the analytical method of determining deflection described on succeeding pages, assume the perfect flexibility of the truss at its joints.

Deflections should always be figured for simultaneous stresses.

Simultaneous live load stresses are usually determined by assuming an equivalent uniform load which will give approximately the same stress in the center panel of the top or bottom chord as given on the stress sheet, the larger cord stress being used. In the calculations, for the deflection at the center of the 396-foot span (see Plates I, II and III), a comparison of the deflection obtained by using the maximum stresses as given on the stress sheet, with the deflection obtained by using simultaneous stresses, showed the total deflection in the former case to be 8 per cent greater than in the latter.

Gross areas are generally used for both tension and compression members. The deformation in any member is directly dependent on its length and unit stress. In tension members, the unit stress and corresponding deformation per unit of length are greater at a section through the rivet holes than at points of gross area. However, on a basis of 6-inch spacing in the body of the member, this greater deformation per unit of length would occur on only approximately one-sixth of the total length of the member, leaving the deformation on five-sixths of the length of the member to be determined by the use of the gross area. From this it will be seen that the use of the gross areas give much closer results than net areas. Merriman and Jacoby suggest that gross areas be used for tension members, but that the modulus of elasticity be slightly reduced.

All members of the truss which are stressed by the load applied at the point at which deflection is to be determined, must be considered in the calculations. However, in calculating the center deflection of a truss having an even number of panels, where both loading and truss are symmetrical, only one-half of the truss need be figured, the final summation being multiplied by two to obtain the total deflection. In this case, for members lying on the center line of the truss, the center line should be considered as dividing in two the total stress, area, and stress due to the applied load at the center. (See M8L8, Plate III.) In a similar truss with an odd number of panels, results sufficiently accurate will be obtained by figuring only one-half the truss, the single load "Q" being replaced by two loads of ½Q, one of which is applied at each of the two panel points immediately adjacent to the center line. In this case, the length of members cut by the center line should be divided by two. The final summation should be multiplied by two as above.

In figuring the end deflection of a draw span having a single

center post, the stress due to the load applied at the end should be considered as distributed over one-half of the post. (See U8L8, Plate IV.)

Deflection due to clearance in pin holes is usually taken care of by decreasing the detailed length of tension members and increasing the detailed length of compression members an amount equal to pin hole clearance. In cases where it is desired to treat pin hole clearance as causing additional deflection, this deflection may be figured by substituting the pin hole clearance for the factor $\frac{PL}{E}$ in the formula for Case II.

Impact stresses are not usually considered in deflection calculations, but on this point there is a difference of opinion, some engineers specifying that impact stresses shall be included.

In making deflection calculations, the use of "+" for tension and "—" for compression members will be found advisable. With this notation, the resulting summation will be "+" when the direction of the deflection agrees with the direction of the applied load, and will be "—" in the opposite case.

NOTES ON TYPICAL DEFLECTION CALCULATIONS.

The use of the formulae and notes on the preceding pages in the analytical determination of deflection in a truss is illustrated in the two typical examples covered by Plates I to V inclusive.

The first example is a 396′ 0″ S. T. Through Pin Connected Baltimore Truss span, the calculations being given on Plates I, II and III.

Plate I shows general dimensions of the truss, stresses for which its members were designed, and their material and gross area, while Plate II shows simultaneous stresses produced in all members by a combination of dead load with an equivalent uniform live load, as explained thereon.

Plate III shows the calculations for deflection at the center of the span and for the deformation of each member under the loading given on Plate II. All panel points of the truss being loaded, formulae used are those of Case II.

Since the truss and loading are symmetrical, only one-half of the truss is figured, the final result being multiplied by two to obtain the total deflection at L8. For member M8L8, which lies on the center line of the truss, one-half the area, total stress and stress "U" are used in the table.

It is assumed that under full load the lower chord will lie in a horizontal line. To obtain this condition, the truss is cambered by decreasing the length of the tension members and increasing the length of compression members an amount equal to the deformation in the member. These detailed lengths are given in the last column on Plate III. Under no load, as when blocked up

during erection, these lengths will give a camber at the center equal to the figured deflection.

The second example is a 458′ 0″ S. T. Through, Riveted Truss Draw Span, the end wedges of which were designed for a vertical uplift of 63,000 pounds. Calculations for deflection are shown on Plates IV and V.

For this draw span, three deflections were figured—(1) the deflection at the end due to dead load swinging, (2) the upward deflection, or uplift, at the end, due to the given or assumed end wedge force, and (3) the deflection at the center of each arm for determining the required camber.

The computations for (1) and (2) are given on Plate IV, and are figured by Cases II and I, respectively. The difference between these two results gives the amount the ends of the span must be raised, by shortening the center links in the top chord, in order that the points L0 may be raised to the level of L8 by the application of the above-mentioned end wedge force.

It should be noted that, in accordance with the note on a preceding page, the total stress and area of the center post U8L8 are considered as divided in two by the center line, and the full stress due to the load applied at L0 is assumed as distributed over this half-post.

In both sets of calculations on this plate, all members are omitted which receive no stress from the applied load at L0, as $\frac{PUL}{E}$ and $\frac{S^2L}{A}$ for these members is zero.

The calculations for (3) and for the deformation of each member of the truss are shown on Plate V. The stresses used in figuring this deflection are obtained by combining two cases of loading, Case I covering dead load and Case II live load. The stresses of Case I are those due to dead load swinging, combined with the end uplift of 63,000 pounds, this being the condition when bridge is closed and ready for traffic. For stresses of Case II, that portion of each arm defined by points L0, U1, U6, L8, L0 is considered as a simple span and the stresses are figured for an equivalent uniform load of 89,000 pounds per panel per truss, this loading giving a stress in top chord U3U6 equal to that given on the original stress sheet. With the exception of this combination of loads, the calculations on this plate are similar to those on Plate III previously described.

In addition to the shortening of U6U8, due to end deflection, as described above, this member must also be shortened to compensate for the cambered position of U6. This compensation, however, is more easily determined by the use of a Williot Diagram, as explained on succeeding pages.

WILLIOT DIAGRAM.

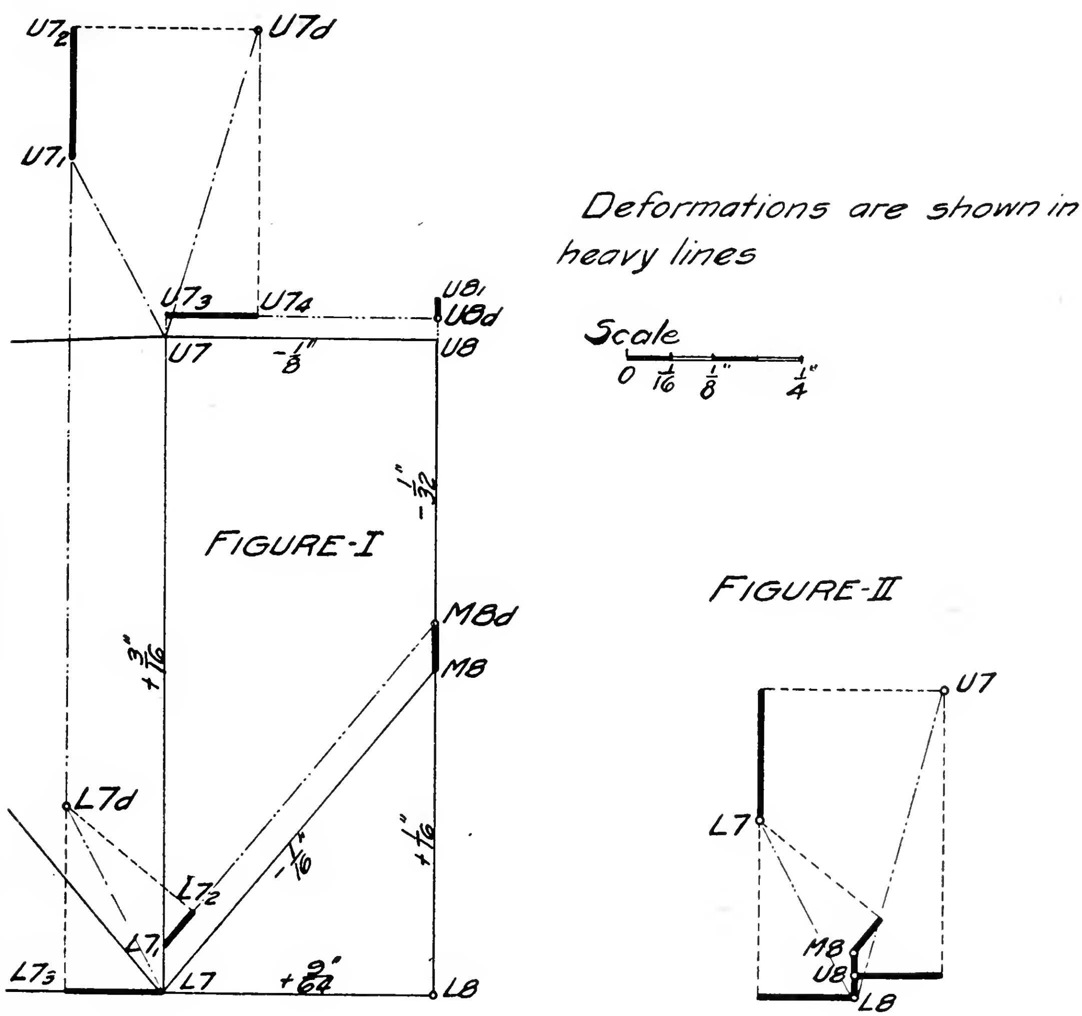
A Williot or Displacement Diagram is a graphical method of determining, under any given system of loading, the displacement of all points of a truss, in all directions in the plane of the truss.

The construction of a Williot Diagram consists of plotting the deformation of the various truss members, these deformations having previously been found by the formulae for deformation,

$$\lambda = \frac{PL}{E}.$$

The advantage of the graphical over the analytical method is that the former, in a single diagram, shows the displacement of all points of the truss in all directions, while the latter, in a single set of calculations, gives the displacement of only one point in one direction. However, where the movement of only one point in one direction is required, such as the center deflection of a span, the analytical method will prove the shorter.

As an illustration of the construction of a Williot Diagram, let it be required to find the displacement of points U7, U8, M8, L7 and L8 of the truss on Plate II.



The deformation of the various members is taken from the table on Plate III, and is marked on the members in Figure I, "—" denoting a decrease in length and "+' an increase. Member U7M8 takes no stress under the assumed loading, hence, is omitted in the diagram.

In constructing any Williot Diagram, it is necessary to assume, as fixed, the location of some point and the direction of one member connecting thereto. In this case, the point L8 and the direction of U8L8 are considered fixed.

In Figure I, the original truss outline is shown in light lines and the panel points are marked U7, U8, M8, L7 and L8, their final displaced positions being marked $U7_d$, $U8_d$, $M8_d$, $L7_d$ and L8, respectively.

The displaced position of M8 is first determined. The line M8L8 represents the normal length of the member, $M8M8_d$ its increase in length, and $L8M8_d$ its total deformed length. Since point L8 and the direction of U8L8 are fixed, it is apparent that $M8_d$ is the required point.

For displaced position of U8, lay off $U8_1M8_d$ equal to the original length of member U8M8. Then laying off $U8_1U8_d$ equal to its decrease in length, $U8_dM8_d$ represents its deformed length and $U8_d$ is the required point.

With points L8 and $M8_d$ known, the displacement of L7 can be determined. Member L7L8 increases in length, the deformation being represented by $L7_3L7$, and the deformed length by $L8L7_3$. Completing the parallelogram $M8 — M8_d — L7_1 — L7$, the line $L7_1M8_d$ equals the normal length of M8L7. From $L7_1$ lay off $L7_1L7_2$ equal to the decrease in the length of the member, thus making $L7_2M8_d$ equal to its deformed length. We now have the length of three sides of a triangle, and the position of one side located. To complete the triangle, draw an arc from $M8_d$ as center, with $M8_dL7_2$ as radius to intersect an arc from L8 as center, with $L8L7_3$ as radius, the intersection of the two arcs being the required point. However, the great length of the members used as radii, and the comparatively small movements of the points, renders the use of arcs unnecessary, and perpendiculars, erected at the ends of the deformed members, give results sufficiently close for any practical purpose. In the diagram, therefore, perpendiculars are erected at $L7_3$ and $L7_2$, their intersection being the required point $L7_d$.

The displaced position of U7 is similarly determined. Complete the parallelogram $L7 — L7_d — U7_1 — U7$, and from $U7_1$ lay off $U7_1U7_2$ equal to the increase in length of U7L7. Also complete the parallelogram $U8 — U8_d — U7_3 — U7$, and from $U7_3$ lay off $U7_3U7_4$ equal to the decrease in length of U7U8. The intersection of perpendiculars at $U7_2$ and $U7_4$ give the required point $U7_d$.

The displacement of all other panel points of the truss could likewise be determined, but, if the diagram of Figure I were completed for the half truss, it would be found quite large, and its

construction too complicated. It is possible, however, to plot the deformations only, the normal length of the members being considered zero. The resultant diagram would be a Williot Diagram, and is shown in Figure II for the panel points of this problem.

Considering the point L8 and the direction of U8L8 fixed as before, we will construct the diagram of Figure II.

In constructing a Williot Diagram the deformations are all laid off parallel to the corresponding truss members, and are likewise both parallel to and equal to the corresponding deformations in Figure I.

The deformation of each member is always laid off, from the fixed point, in the direction in which the free end of the member moves with respect to the fixed point.

With the position of L8 and direction of U8 L8 fixed, as noted above, we will first determine the displaced position of M8. Member M8 L8 increased in length, its free end moving upward with respect to L8. The deformation of the member is correspondingly laid off upward from L8, Figure II, and M8 is the displaced position of the corresponding point of the truss.

Having fixed the position of M8, the displaced position of U8 will next be determined. Member M8 U8 decreases in length, causing the free end to move downward with respect to M8. The deformation in the member is correspondingly laid off downward from M8, and U8 is the displaced position of the corresponding point of the truss.

With points M8 and L8 fixed, we will determine the displaced position of L7. Member L8 L7 increases in length, causing the free end to move to the left, with respect to L8, an amount equal to the deformation in that member. Point L7 is also affected by the change in length of member M8 L7. This member decreases in length, causing the free end to move upward and to the right, with reference to M8, an amount equal to the deformation in that member. Having laid off the deformation of these two members in accordance with the above, the intersection of perpendiculars at their ends will be the displaced position of L7.

Corresponding procedure will determine the displaced position of U7, or any other point of the truss, taken in proper order.

It will be noticed that this construction is simply that of determining the intersection of two arcs of given radii, described from previously determined centers, except that perpendiculars are used in place of arcs, as previously mentioned.

In any Williot Diagram, the assumed fixed point, in this case L8, is called the pole, and when this pole is successively applied to the various panel points, the diagram gives both the amount and direction of the displacement of the points, provided the pole point and the direction of the assumed member remain stationary.

Now, by applying the pole L8 to the various panel points, it is apparent that the displacement of points U7, U8, M8 and L7 with reference to the pole in Figure II, are equal to the displacement

of points $U7_d$, $U8_d$, $M8_d$ and $L7_d$ with reference to the panel points U7, U8, M8 and L7, respectively, in Figure I.

The diagram, when completed, shows the relationship between the various panel points. Any other point might then be taken as the pole, and, on condition that the direction of the assumed member remain fixed, this pole, when applied to the various panel points, will give the amount and direction of their displacement with reference to that pole.

Where both truss and loading are symmetrical about the center line, it is necessary to make the Williot Diagram for only one-half of the truss, the resulting diagram giving the deflection of each panel point and one-half the increase in the length of the truss. For a truss having an even number of panels, as was the case in the above problem, the full deformation of members lying on the center line is used in the diagram. For a truss having an odd number of panels, the assumed point is usually taken at the center of the center panel of the lower chord and the direction of that member is assumed as fixed. In this case, one-half of the deformation of the members cut by the center line is laid off on either side of the assumed point.

In an unsymmetrical truss, or a symmetrical truss, unsymmetrically loaded, a point as near the center of the truss as possible and the direction of a member meeting at that point are usually assumed as fixed. Correction for any error from this assumption is made in three ways, all of which are illustrated in the draw span problem on the succeeding pages.

On account of the triangular nature of the construction of the Williot Diagram, as explained in detail for point L7, in Figure I, it should be borne in mind that no more than three members of the truss, connected at their ends to form a triangle, can be considered at one time.

NOTES ON TYPICAL WILLIOT DIAGRAMS.

The examples used to illustrate the construction and use of Williot Diagrams are the same as those for which deflection was figured analytically on previous pages.

The Williot Diagram for the 396′ 0″ span, the calculations for which are given on Plates I, II and III, is shown on Plate VI. Since the problem illustrated in Figure II was taken from this identical truss, and since the same assumption as to fixed point and direction of one member attached thereto is made, this diagram for points U7, U8, M8, L7 and L8 is the same as Figure II. The displacement of the remainder of the panel points is easily determined by continuing the construction as described for Figure II. It should be noted, however, that, after having located U7 and L7, the displaced positions of U5 and L5 are next found. With these points known, the sub-panel points U6, M6 and L6 may be determined. For panels L3 to L5, the construction is similar.

Having completed the Williot Diagram, the truss displacement or camber diagram on Plate VII may be drawn. The full lines on

this diagram show the assumed position of the truss under full load. The lengths of the members of the truss in this position are those given on Plate III, in columns headed "L" and "Normal Length Full Load." The dot and dash lines show the cambered position of the truss. The lengths of the members in this position are those given in the last column on Plate III. Under the full loading on Plate II, this truss should deflect to the position shown by the full lines. The dotted lines show the deflected position the truss would assume under full load if it had been built to the dimensions represented by the full lines and erected in that position. The above is the assumption made in all deflection calculations and diagrams, and having found the deflection and deformation of the members under this assumption, the tension members are shortened and the compression members lengthened the amount of their deformation, the resultant lengths giving a reverse deflection, or camber, equal at all points to the figured deflection.

For the purpose of this diagram, it is desired that the point L0 move only in a horizontal line, and that member U8L8 remain vertical and move only in a vertical line. To agree with these conditions, the pole must be placed at point "A," which is the intersection of a horizontal line through L0 and a vertical through U8 and L8. This pole, applied at each panel point in succession, gives the displacement of the point, both in amount and direction. Thus for point L1, the line from pole "A" to L1 in the Williot Diagram agrees in amount and direction with the line $L1L1_d$, in the truss displacement diagram. For cambered position of the panel points, the displacement is simply laid off in the opposite direction, as for instance, $L1L1_c$.

On Plates VIII and IX are shown Williot Diagrams for the 458′ 0″ Draw Span, under the loading used in the calculations on Plate V. The deformation of each member is marked on the small truss diagram on Plate VIII.

Since this truss is unsymmetrical, both as to loading and outline, the diagram for the full truss must be drawn. The diagram on Plate VIII is constructed under the assumption that point L4 at the center of the lower chord and the direction of U4L4 are fixed. The method of construction is similar to that explained for the previous problem.

The completed diagram on Plate VIII gives the relative movement of all points under the given assumption, but not the absolute movement. It will be noted that L0 and L8 do not lie in the same horizontal line. Since the truss was designed with these points in the same horizontal line, and since the end bearings of a bridge permit no vertical movement, the assumption that U4L4 remains vertical must, therefore, be in error. The amount the ends of the truss have been revolved, under this assumption, is represented by the vertical component $L0L0_4$ of the line connecting L0 and L8. To bring points L0 and L8 in the same horizontal line, the entire

truss must be revolved about L4, L0 moving upward and L8 downward an amount equal to $\frac{1}{2}L0L0_4$.

This condition is illustrated in the small diagram on the page, the dotted lines showing the position of the truss under the assumption that U4L4 remains vertical, and the full lines, the actual position. When the dotted line truss is revolved about L4 until it coincides with the full lines, U4 moves to the right an amount equal to $\frac{46.14}{114.5} \times .127'' = .0511''$. All upper and lower chord points move vertically an amount in direct proportion to their horizontal distance from L4, and in addition, the top chord points move horizontally an amount equal to $\frac{h}{114.5} \times .127''$, where "h" is the depth of the truss at the point in question.

In revolving the truss, perpendiculars are used in place of arcs of circles, on account of the small movement of the points and the great length of the radii.

The first method of correcting the error in the initial assumption consists of making a new Williot Diagram with point U4 in its corrected position, as previously determined. The diagram on Plate IX was drawn with this correction and shows L0 and L8 in the same horizontal line, as required. This diagram now gives the absolute movement of all points and any point may be taken as the pole.

The second method consists of plotting the correction of each point, as previously determined, on the diagram on Plate VIII. When this is done, it will be found that the location of all points is the same as in the diagram on Plate IX.

The third method consists of selecting any point of reference, plotting all corrections from that point, and measuring the displacements from the several new points thus obtained. In this case, the dotted line truss is revolved about the point of reference and the correction for each panel point figured. These corrections are then plotted from the given point of reference, but opposite in direction to the correction if made at each truss point. If the several plotted points thus obtained are connected by lines, the resultant figure will be a truss, similar to the original truss, and having a length equal to the vertical displacement of the end reactions. In actual practice, therefore, it is unnecessary to figure the corrections, as they may be determined by constructing this small truss. The corresponding panel point on the small truss must coincide with the point of reference.

In the diagram on Plate VIII, L8 is selected as the reference point. The corrections are determined by laying off downward

and to the left of this point a small truss having a length equal to $L0L0_4$. The distances of the various panel points of this small truss, from L8, represent the necessary corrections for the corresponding points in the diagram. Thus $L8L6_3$ represents the correction for L6, $L8U3_3$, the correction for U3, etc. These distances may be checked numerically from information on the plate.

The displacement of any panel point, with reference to L8, measured from the corresponding point on this small truss, will now be found equal in amount and direction to the displacement of the same point with reference to L8 in the corrected diagram on Plate IX.

To be correct, the three methods described above, for correcting error in the initial assumption, must give equal results. For proof, the displacement of U6, with reference to L8, will be considered.

The diagram on Plate IX gives the displacement of this point in its corrected position, as determined by the first method.

In the diagram on Plate VIII, the corrected position of U6, as determined by the second method, is at $U6_2$, the correction being laid off downward and to the right. The pole L8, under this method, moves to $L8_2$.

By the third method, the correction is laid off downward and to the left from L8, the corrected position of the pole L8 being $U6_3$. If the correction for the third method had been laid off from the panel points in the diagram, the corrected position of U6 would be $U6_4$, the correction being laid off upward and to the right.

Lines connecting U6, $U6_2$ and $U6_4$ with $U6_3$, $L8_2$ and L8, respectively, are found to be exactly equal by construction, and by scale, are equal in length, and have the same direction, as line U6L8, Plate IX, thus proving the proposition.

Plate X shows a truss displacement diagram for the draw span above described. Its construction is similar to that described previously for the 396′ 0″ simple span. The pole is taken at L8, since this point is the center of the draw span and can have no movement. This diagram clearly shows the amount which the top chord links U6U8 must be shortened to compensate for the camber in the truss. An interesting feature of this diagram is the lower chord deflection line, which shows that the maximum deflection does not occur under L4, as assumed in the calculations on page No. 9, but under point L3. This fact discloses one of the advantages of the use of Williot Diagrams.

ACKNOWLEDGMENT.

The writers desire to thank Mr. F. W. Dencer, Engineer; Mr. A. T. Tompt, Drawing Room Engineer, and Mr. A. P. Ludberg, Draftsman, of the Gary Plant of the American Bridge Company, for many valuable suggestions and helps in the preparation of this paper.

Note:—The discussion of the above paper and the one following will be found on page 154.

February, 1916

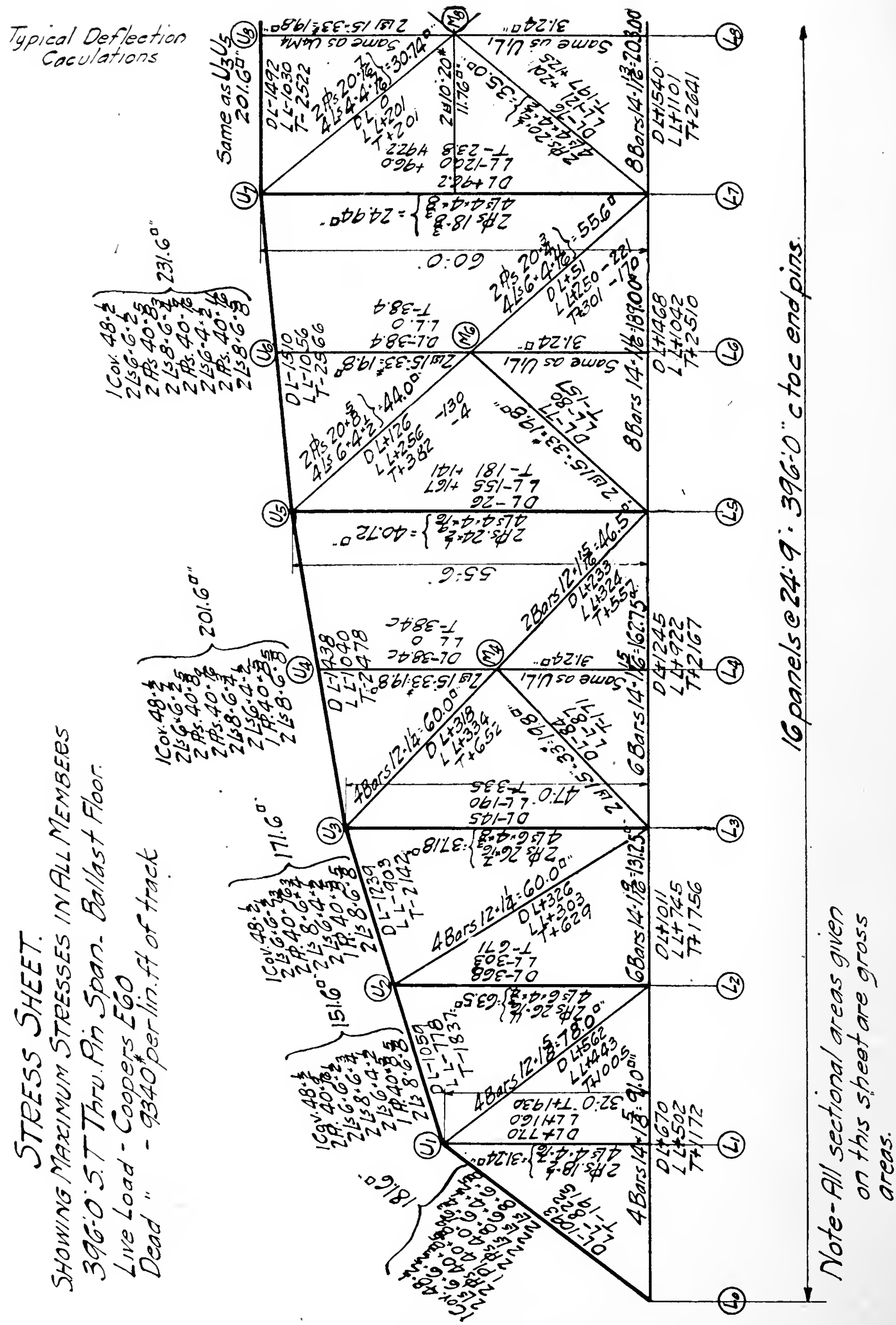

Typical Deflection Caculations
STRESS SHEET.
SHOWING MAXIMUM STRESSES IN ALL MEMBERS
396'-0" S.T. Thru. Pin Span. Ballast Floor.
Live Load - Coopers E60
Dead " - 9340# per lin. ft of track
16 panels @ 24'-9" : 396'-0" c to c end pins.
Note - All sectional areas given on this sheet are gross areas.

Plate 1.

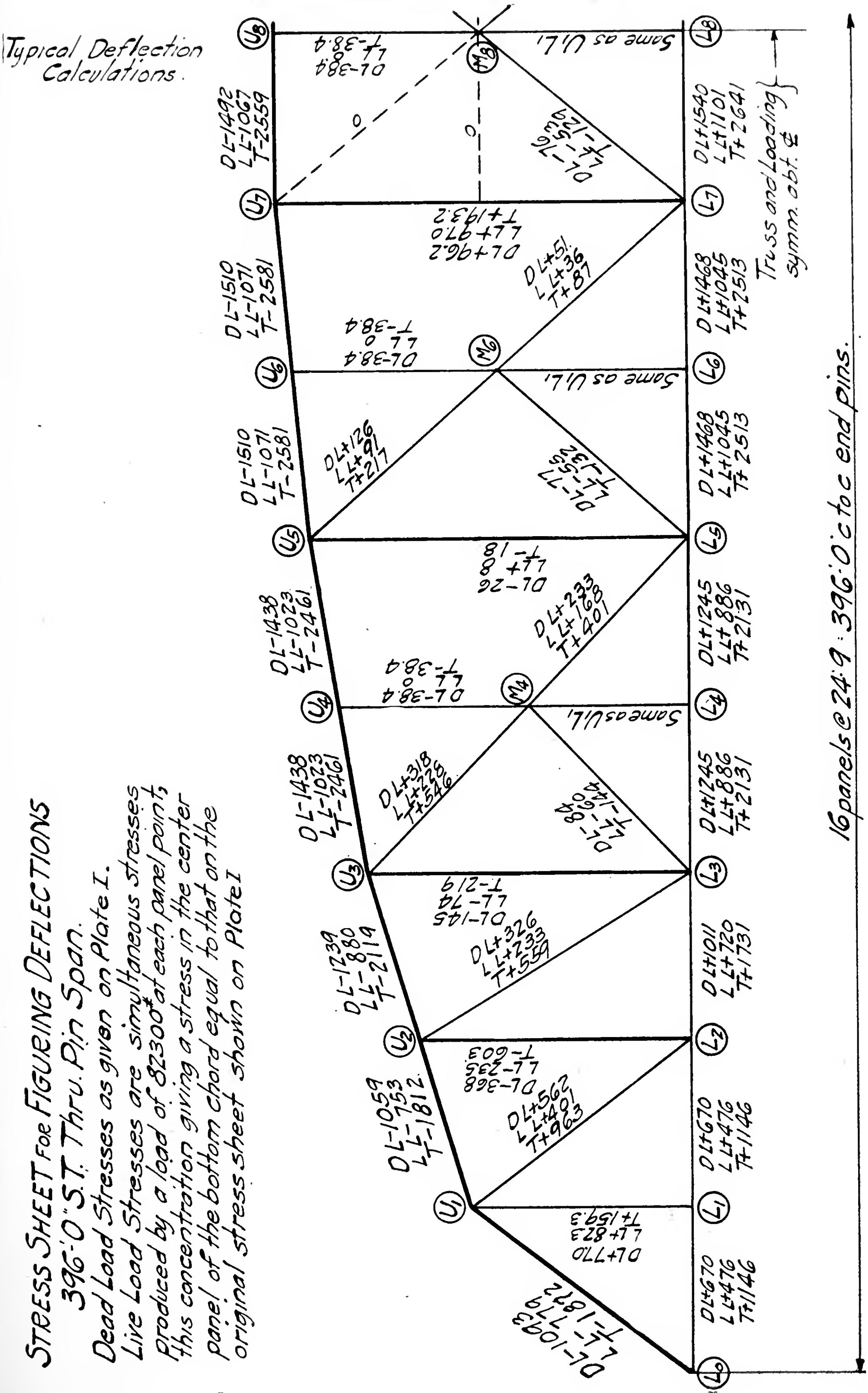

Typical Deflection Calculations.
STRESS SHEET FOR FIGURING DEFLECTIONS
396'-0" S.T. Thru. Pin Span.
Dead Load Stresses as given on Plate I.
Live Load Stresses are simultaneous stresses produced by a load of 82300# at each panel point; this concentration giving a stress in the center panel of the bottom chord equal to that on the original stress sheet shown on Plate I
16 panels @ 24'-9" = 396'-0" c to c end pins.
Truss and Loading symm. abt. ℄
U1 U2 U3 U4 U5 U6 U7 U8
L0 L1 L2 L3 L4 L5 L6 L7 L8
M4 M6 M8
Same as U.L.
DL-1059 LL-753 T-1812
DL-1239 LL-880 T-2119
DL-1438 LL-1023 T-2461
DL-1510 LL-1071 T-2581
DL-1492 LL-1067 T-2559
DL+670 LL+476 T+1146
DL+1011 LL+720 T+1731
DL+1245 LL+886 T+2131
DL+1468 LL+1045 T+2513
DL+1540 LL+1101 T+2641
DL+770 LL+82.3 T+159.3
DL+562 LL+401 T+963
DL-368 LL-235 T-603
DL+326 LL+233 T+559
DL-145 LL-74 T-219
DL+318 LL+228 T+546
DL-38.4 LL 0 T-38.4
DL+233 LL+168 T+401
DL-26 LL+8 T-18
DL+126 LL+91 T+217
DL+51 LL+36 T+87
DL+96.2 LL+97.0 T+193.2

Plate 2.

TYPICAL DEFLECTION CALCULATIONS

DEFLECTION CALCULATIONS - 396'-0" SPAN

Member	Length in ins. L	Area sq. in. A	DEAD LOAD + LIVE LOAD. Stress in lbs S	Unit Stress lbs $P = S/A$	Deformation $\lambda = PL/E$	U in pounds 1# at L8	$\Delta = \frac{PUL}{E}$	Normal Length Full Load	λ Frac	Length as detailed.
L0U1	485.4	181.60	− 1872000	− 10310	− .17256	− .6320	+ .109057	40'-5 29/64	− 11/64	40'-5 5/8
U1U2	310.3	151.60	− 1812000	− 11960	− .12795	− .6547	+ .083769	25'-10 11/32	− 8/64	25'-10 15/32
U2U3	310.3	171.60	− 2119000	− 12350	− .13214	− .8253	+ .109055	25'-10 11/32	− 9/64	25'-10 31/64
U3U4	301.3	201.60	− 2461000	− 12210	− .12685	− 1.1311	+ .143480	25'-1 11/32	− 8/64	25'-1 15/32
U4U5	301.3	201.60	− 2461000	− 12210	− .12685	− 1.1311	+ .143480	25'-1 11/32	− 8/64	25'-1 15/32
U5U6	298.2	231.60	− 2581000	− 11140	− .11455	− 1.4497	+ .166063	24'-10 7/32	− 7/64	24'-10 21/64
U6U7	298.2	231.60	− 2581000	− 11140	− .11455	− 1.4497	+ .166063	24'-10 7/32	− 7/64	24'-10 21/64
U7U8	297.0	201.60	− 2559000	− 12700	− .13006	− 1.4437	+ .187768	24'-9	− 8/64	24'-9 1/8
L0L1	297.0	91.00	+ 1146000	+ 12580	+ .12880	+ .3867	+ .049850	24'-9	+ 8/64	24'-8 7/8
L1L2	297.0	91.00	+ 1146000	+ 12580	+ .12880	+ .3867	+ .049850	24'-9	+ 8/64	24'-8 7/8
L2L3	297.0	131.25	+ 1731000	+ 13190	+ .13508	+ .6265	+ .084628	24'-9	+ 9/64	24'-8 55/64
L3L4	297.0	162.75	+ 2131000	+ 13100	+ .13410	+ .7899	+ .105900	24'-9	+ 9/64	24'-8 55/64
L4L5	297.0	162.75	+ 2131000	+ 13100	+ .13410	+ .7899	+ .105900	24'-9	+ 9/64	24'-8 55/64
L5L6	297.0	189.00	+ 2513000	+ 13290	+ .13610	+ 1.1148	+ .151724	24'-9	+ 9/64	24'-8 55/64
L6L7	297.0	189.00	+ 2513000	+ 13290	+ .13610	+ 1.1148	+ .151724	24'-9	+ 9/64	24'-8 55/64
L7L8	297.0	203.00	+ 2641000	+ 13010	+ .13324	+ 1.8560	+ .247293	24'-9	+ 9/64	24'-8 55/64
U1L2	485.4	78.00	+ 963000	+ 12350	+ .20671	+ .3920	+ .081030	40'-5 29/64	+ 13/64	40'-5 1/4
U2L2	474.0	63.50	− 603000	− 9500	− .15524	− .3100	+ .048124	39'-6	− 10/64	39'-6 5/32
U2L3	559.4	60.00	+ 559000	+ 9320	+ .17930	+ .3066	+ .055100	46'-7 23/64	+ 11/64	46'-7 3/16
U3L3	564.0	37.18	− 219000	− 5900	− .11474	− .2606	+ .029901	47'-0	− 7/64	47'-0 7/64
U3M4	409.5	60.00	+ 546000	+ 9100	+ .12849	+ .4481	+ .057576	34'-1 35/64	+ 8/64	34'-1 27/64
M4L5	409.5	46.50	+ 401000	+ 8630	+ .12186	+ .4481	+ .054605	34'-1 35/64	+ 8/64	34'-1 27/64
U5L5	666.0	40.72	− 18000	− 440	− .01010	− .3085	+ .003120	55'-6	− 1/64	55'-6 1/64
U5M6	446.2	44.00	+ 217000	+ 4940	+ .07600	+ .4941	+ .037552	37'-2 13/64	+ 5/64	37'-2 1/8
M6L7	446.2	55.64	+ 87000	+ 1560	+ .02400	+ .4941	+ .011858	37'-2 13/64	+ 2/64	37'-2 11/64
U7L7	720.0	24.94	+ 193200	+ 7750	+ .19220	+ .1301	+ .025000	60'-0	+ 12/64	59'-11 13/16
M8L7	466.7	35.00	− 129000	− 3690	− .05937	− .6481	+ .038478	38'-10 45/64	− 4/64	38'-10 49/64
M8L8	360.0	15.62	+ 79650	+ 5100	+ .06331	+ .5000	+ .031655	30'-0	+ 4/64	29'-11 15/16
U1L1	384.0	31.24	+ 159300	+ 5100	+ .06753	0	0	32'-0	+ 4/64	31'-11 15/16
L3M4	409.5	19.80	− 144000	− 7280	− .10279	0	0	34'-1 35/64	− 7/64	34'-1 21/32
U4M4	333.0	19.80	− 38400	− 1940	− .02230	0	0	27'-9	− 1/64	27'-9 1/64
M4L4	282.0	31.24	+ 159300	+ 5100	+ .04959	0	0	23'-6	+ 3/64	23'-5 61/64
L5M6	446.2	19.80	− 132000	− 6670	− .10270	0	0	37'-2 13/64	− 7/64	37'-2 5/16
U6M6	360.0	19.80	− 38400	− 1940	− .02408	0	0	30'-0	− 2/64	30'-0 1/32
M6L6	333.0	31.24	+ 159300	+ 5100	+ .05856	0	0	27'-9	+ 4/64	27'-8 15/16
U8M8	360.0	19.80	− 38400	− 1940	− .02408	0	0	30'-0 1/32	− 2/64	30'-0 1/16
							+2.529603			
							2			
						$\Sigma \frac{PUL}{E} =$	5.059206	= 5 1/16		

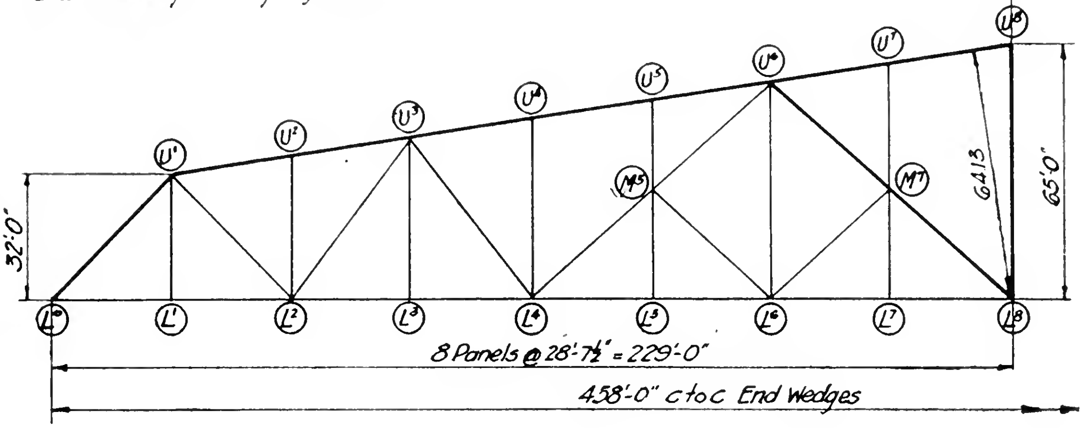
Plate 3.

458'-0" S.T THRU RIV TRUSS
DRAW SPAN.

TYPICAL DEFLECTION CALCULATIONS.

D.L = 3900# per lin ft of track

Truss symmetrical about this ℄



CALCULATIONS FOR DEFLECTIONS AT END.								
GENERAL DIMENSIONS			DOWNWARD DEFLECTION - DEAD LOAD SWINGING				UPLIFT - 63000# ON WEDGE	
MEMBER	Length of member in feet. L	Gross Area in sq. inches A	Dead load - Stress swinging in pounds S	Dead Load Unit Stress in pounds $P = S/A$	Stress due to 63# at L^0 U	PUL	Stress for 63000# uplift S	$\frac{S^2L}{A}$
L^0U^1	42.94	72.4	+ 53,000	+ 730	+ 85.0	+ 2,664,400.	− 85,000	+ 4,284,600,000
U^1U^3	58.02	55.9	+ 106,000	+ 1900	+ 100.0	+ 11,002,200	− 100,000	+ 10,379,400,000
U^3U^6	87.03	61.9	+ 309,000	+ 4990	+ 158.0	+ 68,643,400.	− 158,000	+ 35,099,200,000
U^6M^7	39.89	81.4	− 375,000	− 4610	− 37.0	+ 6,799,700	+ 37,000	+ 670,900,000
M^7L^8	39.89	93.4	− 415,000	− 4440	− 37.0	+ 6,553,100	+ 37,000	+ 584,700,000
U^6U^8	58.02	75.0	+ 838,000	+ 11170	+ 225.0	+ 145,818,800	− 225,000	+ 39,164,200,000
L^0L^2	57.25	44.3	− 35,000	− 790	− 56.0	+ 2,532,900.	+ 56,000	+ 4,052,700,000
L^2L^4	57.25	66.8	− 197,000	− 2950	− 131.0	+ 22,118,100	+ 131,000	+ 14,708,000,000
L^4L^6	57.25	56.8	− 524,000	− 9230	− 195.0	+ 102,989,600.	+ 195,000	+ 38,326,300,000
L^6L^8	57.25	56.8	− 524,000	− 9230	− 195.0	+ 102,989,600	+ 195,000	+ 38,326,300,000
U^1L^2	42.94	41.8	− 104,000	− 2490	− 63.0	+ 6,730,000	+ 63,000	+ 4,076,800,000
U^3L^2	50.36	32.5	+ 162,000	+ 4980	+ 57.0	+ 14,307,400.	− 57,000	+ 5,034,100,000
U^3L^4	50.36	38.4	− 190,000	− 4950	− 45.0	+ 11,212,100.	+ 45,000	+ 2,655,500,000
L^4M^5	39.89	57.8	+ 305,000	+ 5280	+ 54.0	+ 11,367,500	− 54,000	+ 2,012,600,000
M^5U^6	39.89	66.8	+ 345,000	+ 5170	+ 53.0	+ 10,919,600.	− 53,000	+ 1,677,500,000
U^8L^8	65.00	18.8	− 161,000	− 8590	− 36.5	+ 20,371,800.	+ 36,500	+ 4,618,450,000
						ΣPUL = + 547,020,200.	$\Sigma \frac{S^2L}{A}$ = + 205,671,250,000	

By Case II Δ at $L^0 = \Sigma \frac{PUL}{QE} = \frac{547{,}020{,}200 \times 12}{63 \times 29{,}000{,}000} = 3.60 = 3\frac{19}{32}$"

Q was taken at 63#, as stresses for 63000# were given on Stress Sheet.

By Case I, Uplift due to 63000# $= \Delta = \frac{1}{WE} \Sigma \frac{S^2L}{A}$

$= \frac{205{,}671{,}250{,}000 \times 12}{63000 \times 29{,}000{,}000} = 1.35 = 1\frac{11}{32}$"

Total Deflection − Uplift = 3.60 − 1.35 = 2.25. Shorten U^6U^8 $\frac{2.25 \times 64.13}{229} = .63 = \frac{5}{8}$" due to deflection. To this figure add decrease on account of Camber.

Plate 4.

Typical Deflection Calculations.

458'-0" S.T. THRU RIV. DRAW SPAN.

Calculations for Detailed Length of Members and Camber at Center of each Arm.
Case I D.L. combined with 63000# uplift.
Case II L.L. of 89000# per panel per truss.

Member	Length in ins. L	Gross Area sq. in A	Case I Stress in kips	Case II Stress in kips	Case I & II combined Stress: S	Unit Stress in lbs $P = \frac{S}{A}$	Deformation $\lambda = \frac{PL}{E}$	U in lbs. (1# at L4)	$\Delta = \frac{PUL}{E}$	Normal Length Full Load	λ Frac.	Length as detailed
L0U1	515.2	72.4	− 32.	−417.	−449.	−6201	−.11016	− .673	+.07413	42'-11 7/32	−7/64	42'-11 21/64
U1U2	348.1	55.9	+ 6.	−420.	−414.	−7406	−.08891	− .789	+.07015	29'-0 1/8	−6/64	29'-0 7/32
U2U3	348.1	55.9	+ 6.	−420.	−414.	−7406	−.08891	− .789	+.07015	29'-0 1/8	−6/64	29'-0 7/32
U3U4	348.1	61.9	+ 151.	−448.	−297.	−4798	−.05759	−1.258	+.07245	29'-0 1/8	−4/64	29'-0 3/16
U4U5	348.1	61.9	+ 151.	−448.	−297.	−4798	−.05759	−1.258	+.07245	29'-0 1/8	−4/64	29'-0 3/16
U5U6	348.1	61.9	+ 151.	−448.	−297.	−4798	−.05759	−1.258	+.07245	29'-0 1/8	−4/64	29'-0 3/16
U6M7	478.7	81.4	− 338.	−384.	−722.	−8869	−.14642	− .718	+.10512	39'-10 23/32	−9/64	39'-10 55/64
M7L8	478.7	93.4	− 378.	−447.	−825.	−8832	−.14581	− .718	+.10469	39'-10 23/32	−9/64	39'-10 55/64
L0L1	343.5	44.3	+ 21.	+277.	+298.	+6726	+.07968	+ .45	+.03586	28'-7 1/2	+5/64	28'-7 27/64
L1L2	343.5	44.3	+ 21.	+277.	+298.	+6726	+.07968	+ .45	+.03586	28'-7 1/2	+5/64	28'-7 27/64
L2L3	343.5	66.8	− 66.	+460.	+394.	+5898	+.06986	+1.035	+.07231	28'-7 1/2	+4/64	28'-7 7/16
L3L4	343.5	66.8	− 66.	+460.	+394.	+5898	+.06986	+1.035	+.07231	28'-7 1/2	+4/64	28'-7 7/16
L4L5	343.5	56.8	− 329.	+320.	− 9.	− 158	−.00188	+ .513	−.00096	28'-7 1/2	0	28'-7 1/2
L5L6	343.5	56.8	− 329.	+320.	− 9.	− 158	−.00188	+ .513	−.00096	28'-7 1/2	0	28'-7 1/2
L6L7	343.5	56.8	− 329.	+320.	− 9.	− 158	−.00188	+ .513	−.00096	28'-7 1/2	0	28'-7 1/2
L7L8	343.5	56.8	− 329.	+320.	− 9.	− 158	−.00188	+ .513	−.00096	28'-7 1/2	0	28'-7 1/2
U1L1	384.0	31.3	+ 37.	+ 89.	+126.	+4025	+.05330	0	0	32'-0	+3/64	31'-11 61/64
U1L2	515.2	41.8	− 41.	+207.	+166.	+3976	+.07055	+ .497	+.03506	42'-11 7/32	+5/64	42'-11 9/64
U2L2	440.6	19.8	− 19.	0	− 19.	− 959	−.01458	0	0	36'-8 9/16	−1/64	36'-8 37/64
U3L2	604.3	32.5	+ 105.	− 79.	+ 26.	+ 800	+.01666	− .449	−.00748	50'-4 9/32	+1/64	50'-4 17/64
U3L3	497.2	31.3	+ 37.	+ 89.	+126.	+4025	+.06901	0	0	41'-5 5/32	+4/64	41'-5 3/32
U3L4	604.3	38.4	− 145.	− 34.	−179.	−4661	−.09713	+ .358	−.03477	50'-4 9/32	−6/64	50'-4 3/8
U4L4	553.7	19.8	− 19.	0.	− 19.	− 959	−.01832	0	0	46'-1 23/32	−1/64	46'-1 47/64
L4M5	478.7	57.8	+ 251.	+168.	+419.	+7249	+.11966	+1.015	+.12145	39'-10 23/32	+8/64	39'-10 19/32
M5U6	478.7	66.8	+ 292.	+231.	+523.	+7829	+.12925	+1.015	+.13119	39'-10 23/32	+8/64	39'-10 19/32
U5M5	276.9	14.4	− 19.	0.	− 19.	−1319	−.01259	0	0	23'-0 7/8	−1/64	23'-0 57/64
M5L5	333.4	31.3	+ 37.	+ 89.	+126.	+4025	+.04628	0	0	27'-9 13/32	+3/64	27'-9 23/64
M5L6	478.7	19.8	− 26.	− 63.	− 89.	−4494	−.07420	0	0	39'-10 23/32	−5/64	39'-10 51/64
U6L6	666.8	54.3	+ 73.	+178.	+251.	+4622	+.10629	0	0	55'-6 27/32	+7/64	55'-6 47/64
L6M7	478.7	19.8	− 26.	− 63.	− 89.	−4494	−.07420	0	0	39'-10 23/32	−5/64	39'-10 51/64
M7L7	333.4	31.3	+ 37.	+ 89.	+126.	+4025	+.04628	0	0	27'-9 13/32	+3/64	27'-9 23/64

$\Sigma \frac{PUL}{E} = +1.09954 = 1\frac{3}{32}$

Plate 5.

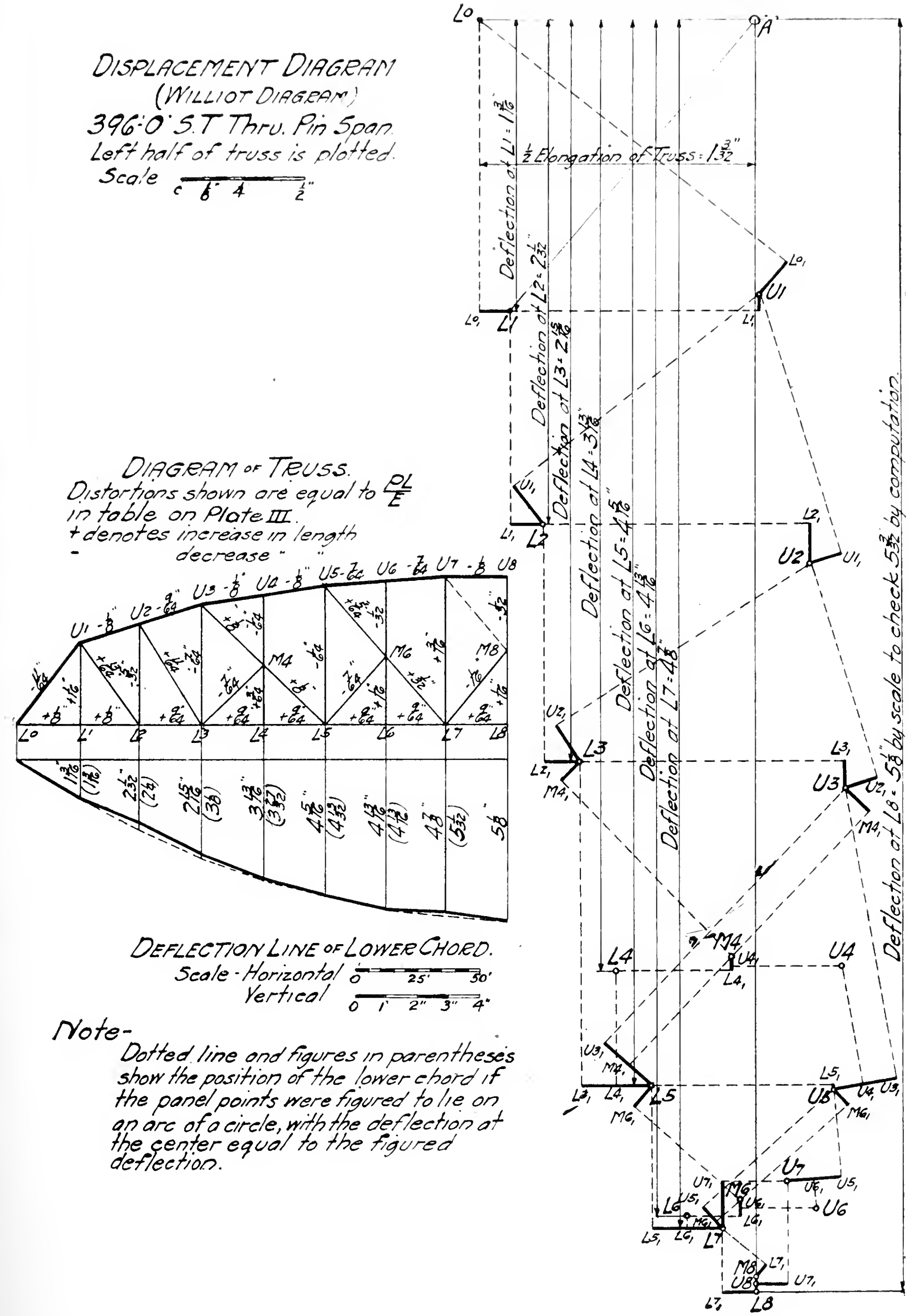

DISPLACEMENT DIAGRAM
(WILLIOT DIAGRAM)
396'-0" S.T. Thru. Pin Span.
Left half of truss is plotted.
DIAGRAM OF TRUSS.
Distortions shown are equal to PL/E in table on Plate III.
+ denotes increase in length
- decrease
DEFLECTION LINE OF LOWER CHORD.
Scale - Horizontal
Vertical
Note-
Dotted line and figures in parentheses show the position of the lower chord if the panel points were figured to lie on an arc of a circle, with the deflection at the center equal to the figured deflection.
Deflection at L8 = 5 5/8" by scale to check 5 3/32" by computation.

Plate 6.

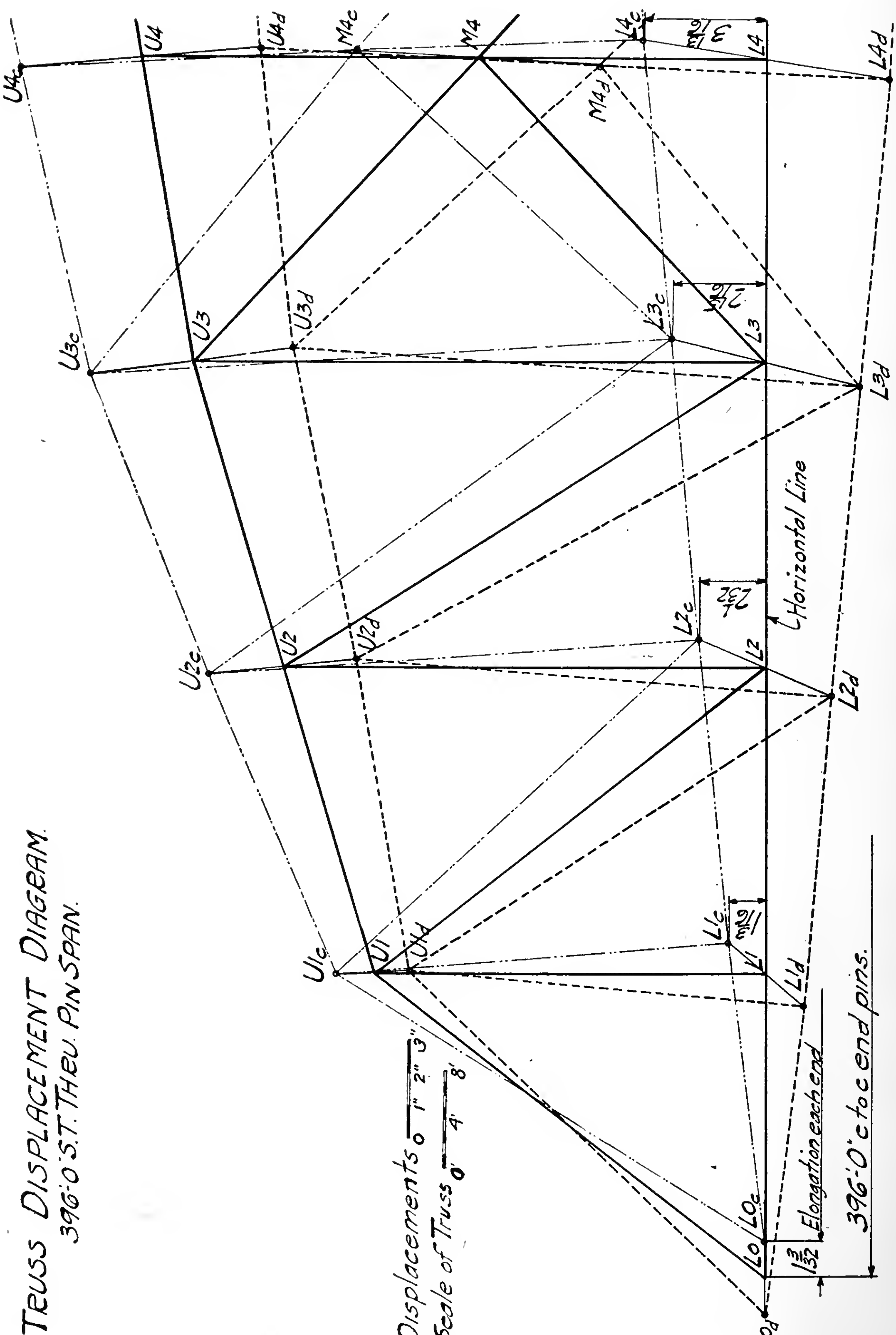

TRUSS DISPLACEMENT DIAGRAM.
396'-0" S.T. THRU. PIN SPAN.
Displacements 0 1" 2" 3"
Scale of Truss 0' 4' 8'
Horizontal Line
Elongation each end
$1\frac{3}{32}$
396'-0" c to c end pins.
U4c
U4
U4d
M4c
M4
L4c
L4
L4d
M4d
U3c
U3
U3d
L3c
L3
L3d
U2c
U2
U2d
L2c
L2
L2d
U1c
U1
U1d
L1c
L1
L1d
Lo
Loc
Lod

Plate 7.

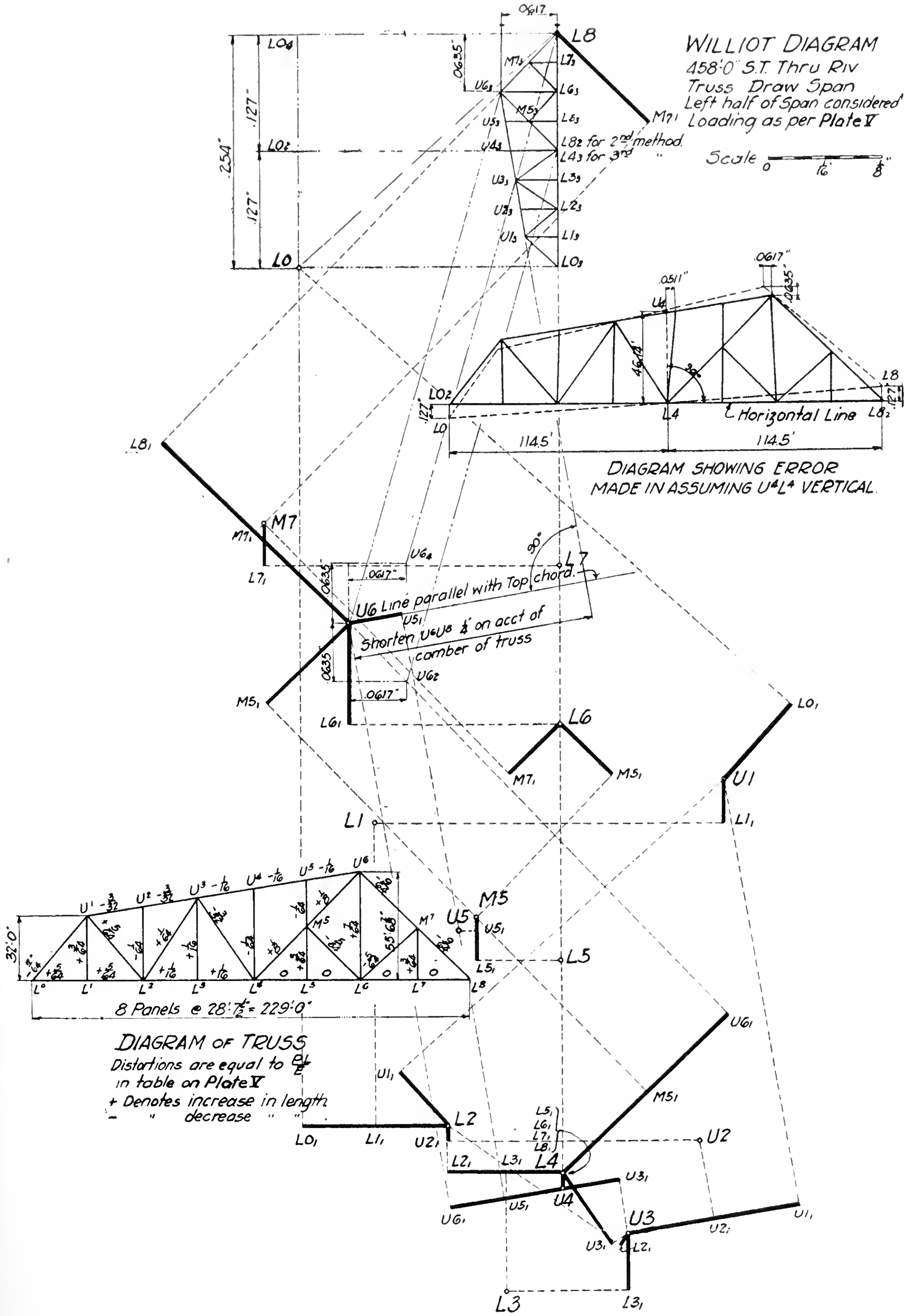
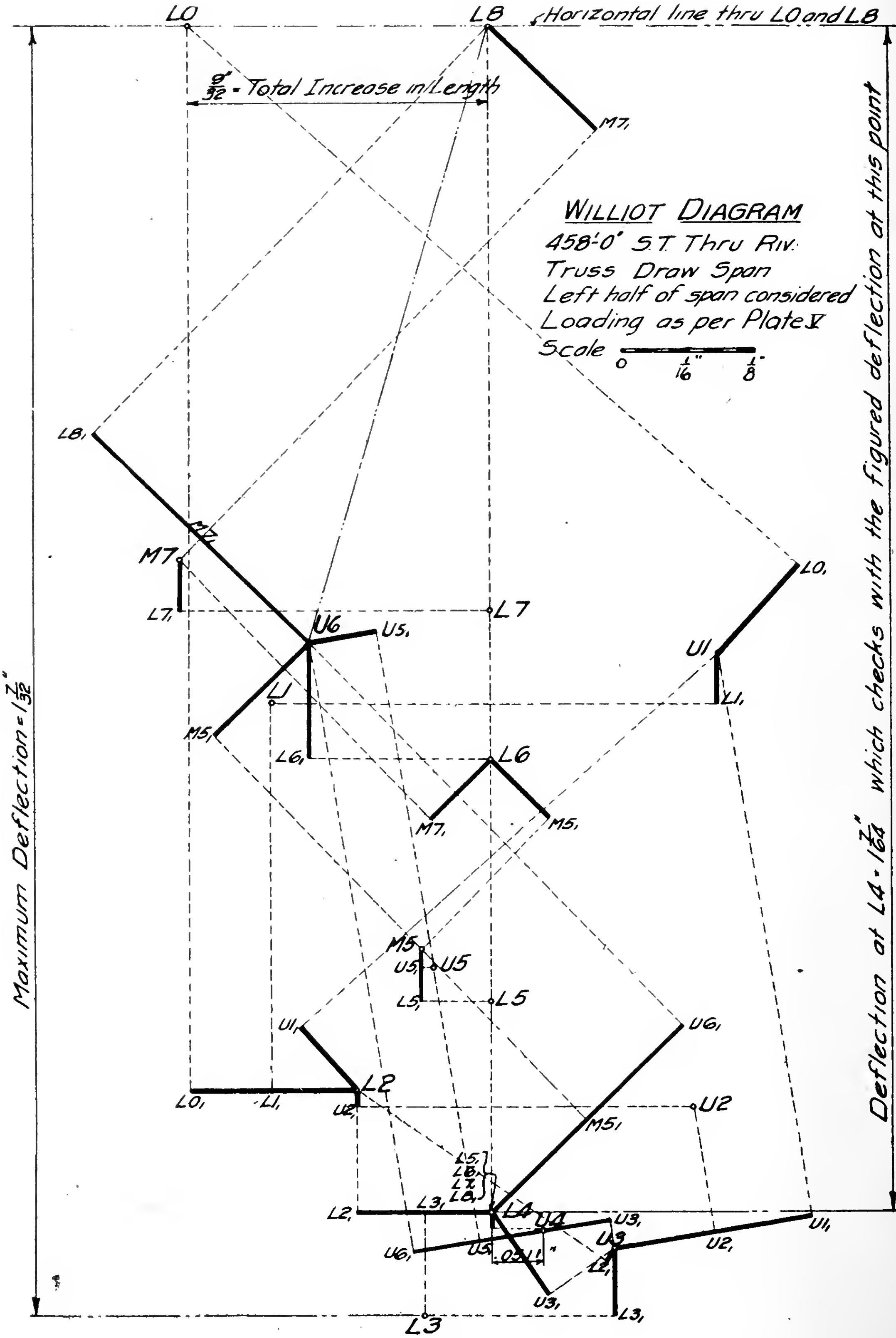

WILLIOT DIAGRAM
458'0" S.T. Thru Riv
Truss Draw Span
Left half of Span considered
Loading as per Plate V
Scale
L82 for 2nd method.
L43 for 3rd "
DIAGRAM SHOWING ERROR
MADE IN ASSUMING U4L4 VERTICAL.
Horizontal Line
114.5'
114.5'
U6 Line parallel with Top chord.
Shorten U6U8 ⅛" on acct of
camber of truss
8 Panels @ 28'-7½" = 229'-0"
DIAGRAM OF TRUSS
Distortions are equal to $\frac{pl}{E}$
in table on Plate V
+ Denotes increase in length
– " decrease "

Plate 8.



Horizontal line thru L0 and L8
9/32" = Total Increase in Length
WILLIOT DIAGRAM
458'-0" S.T. Thru Riv. Truss Draw Span
Left half of span considered
Loading as per Plate V
Scale 0 1/16" 1/8"
Maximum Deflection = 1 7/32"
Deflection at L4 = 1 7/64" which checks with the figured deflection at this point
L0
L8
M7
L7
U6
U5
U1
L1
L6
M5
L5
L2
U2
L4
U4
U3
L3
.05 1/4"

Plate 9.

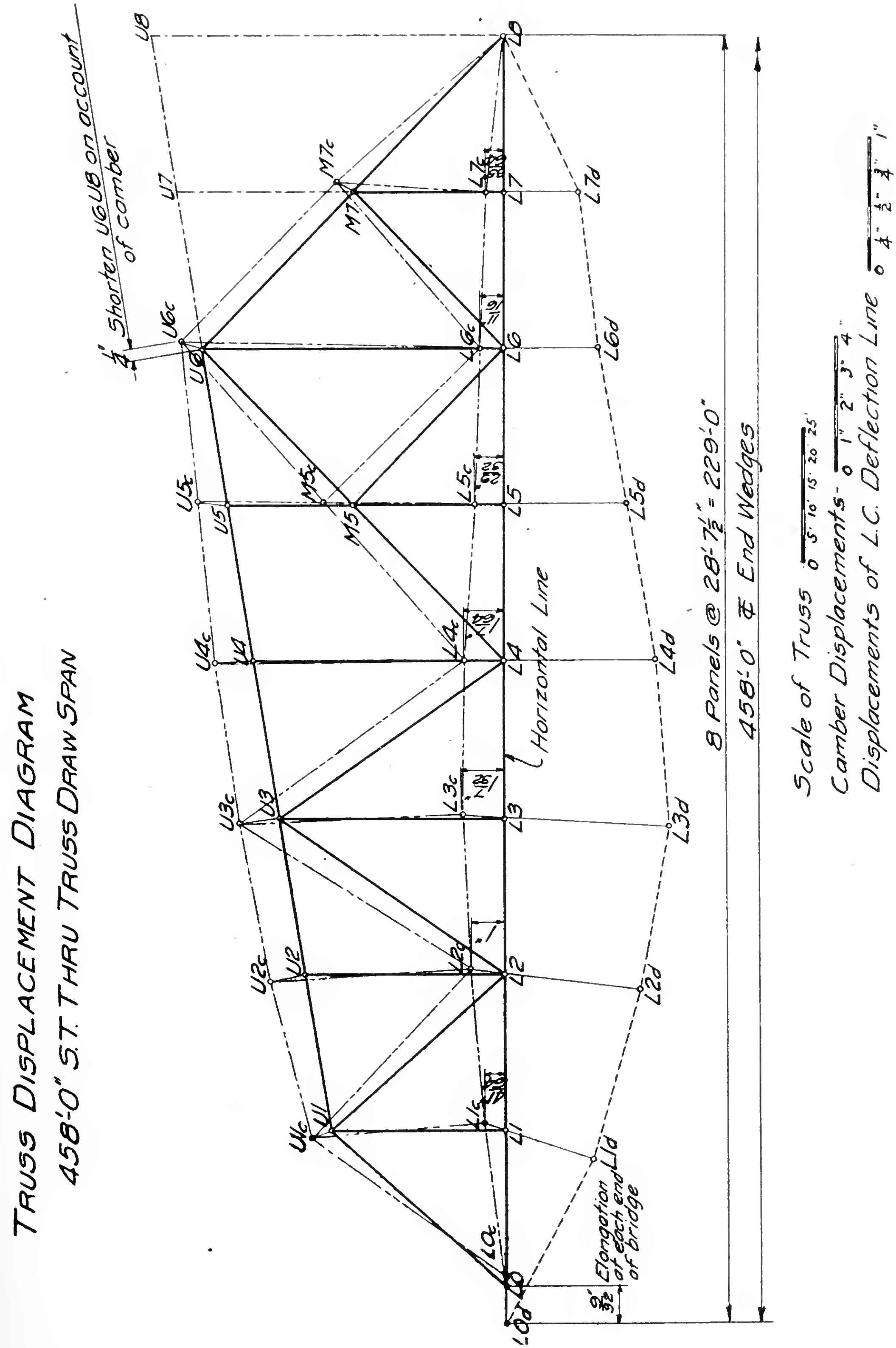

TRUSS DISPLACEMENT DIAGRAM
458'-0" S.T. THRU TRUSS DRAW SPAN
Shorten U6U8 on account of camber
Horizontal Line
8 Panels @ 28'-7½" = 229'-0"
458'-0" ℄ End Wedges
Elongation of each end of bridge
Scale of Truss 0 5' 10' 15' 20' 25'
Camber Displacements 0 1" 2" 3" 4"
Displacements of L.C. Deflection Line 0 ¼" ½" ¾" 1"

Plate 10.

THE USE OF INFLUENCE LINES

By R. W. Flowers, Assoc. W. S. E., and H. N. Jones, Jr., Assoc. W. S. E.

Presented November 29, 1915.

Influence lines in general are lines which represent the variation of moment, shear, panel load, stress or similar function at a particular point in a structure or in any particular member due to a unit load moving over the structure. Influence lines are particularly useful in representing graphically the influence upon the value of any function of the loads on different parts of a structure and the effect of moving those loads in either direction.

In Part I of "Modern Framed Structures," by Johnson, Bryan and Turneaure, an influence line is defined as follows: A curve representing the variation of moment, shear, panel load, stress, or any similar function, at a particular point in a structure or in any particular member, due to a load unity moving over the structure, is called an influence line. The difference between an influence line and an ordinary moment or shear curve is that the former represents the variation in the function for a particular point, due to a moving load, while the latter represents the variation in the function along the structure due to some fixed load.

Suppose that the bending moment at C in the beam AB is to be investigated. (Fig. 1, Plate A.) Consider the unit load P as moving over the beam from B to A. So long as it is between B and C the bending moment is equal to $\frac{Pxa}{L}$. This moment varies directly with x and may, therefore, be represented by the straight line B′D drawn with reference to the horizontal axis A′B′ so that the ordinate y at any point is equal to $\frac{Pxa}{L}$ the moment at C for load P placed at a distance x from B. After the load P passes the point C, the moment at C (considering forces [the right reaction] to the right of C) is equal to $\frac{Px'a'}{L}$. This moment is represented by the line A′D. The line A′DB′ then represents the moment at C due to the load P moving across the beam AB. Suppose that a series of unit loads, P_1, P_2, etc., are on the beam, the total bending movement at C then is equal to the sum of the respective ordinates of the influence line. If the load consists of a unit uniform load of any length, the total moment due to this load is equal to the area within the limiting ordinates.

The left reaction or end shear of the beam AB due to a unit

load P placed at any point on the beam is $\frac{Px}{L}$. The influence line for left reaction is then the straight line A″B′ drawn with A′A″ equal to P. The influence line for the right reaction may be drawn below the axis A′B′ with the ordinate B′B″ equal to P. (Fig. 2, Plate A.)

The total moment, shear or other function for any series of loads is the sum of the products of all loads and their respective ordinates to the influence line.

In general, for a maximum moment, shear or other function for a series of concentrated loads (as a wheel loading diagram), one of the heavy loads should be placed at a peak of the influence line. Note that it is not always possible to assume exactly which load to place at the peak and more than one trial may be necessary.

TRUSSES WITH HORIZONTAL CHORDS AND SINGLE WEB SYSTEMS.

The influence line for the moment at any joint of the loaded chord is the same as for a beam. The criterion for maximum moment is that "The average load per unit length on the left of the joint must be equal to the average load on the whole span."

Note: To find the maximum floor beam reaction R for two panels of lengths d_1 and d_2, find the maximum bending moment (M) at the intermediate panel point for a beam of length equal to $d_1 + d_2$. The maximum floor beam reaction equals $M\frac{d_1 + d_2}{d_1\ d_2}$, or if $d_1 = d_2 = d$, R equals $\frac{2M}{d}$.

To construct the influence line for the shear in the panel to the left of any joint C, let m′ equal the number of panels to the right of that joint; m equal the number of panels to the left, and n equal the total number of panels.

For a unit load placed to the right of joint C, the shear in the panel is equal to the left hand reaction, and for a unit load to the left of joint C the negative shear in the panel is equal to the right hand reaction. The influence line from B to C and from A to E can be constructed as in Fig. 3, Plate A. The ordinate C′D is equal to $\frac{m1}{n}$ and E′F equal to $\frac{m - 1}{n}$. For the panel EC the shear will vary uniformly as the load moves from C to E and the influence line will be the straight line DF. The criterion for maximum shear in any panel is that "The average load in the panel must be equal to the average load on the whole span."

The advantage of the use of influence lines is well illustrated

by their application to the following problem taken from the design of the 79th street grade separation.

The 79th street grade separation has three levels—the upper

INFLUENCE LINES FOR COLUMN LOADS.

one for the C. R. I. & P. R. R., the intermediate one for the C. & E. I. R. R., and the lower level for 79th street, which is slightly depressed. As these rights of way all cross each other obliquely, the structure is very irregular and the distribution of the live loads is difficult to determine.

We will find the maximum live load that Col. C3, Plate I, can receive from the five C. R. I. & P. R. R. tracks.

Plate I shows to scale in heavy lines the portion of the upper level that distributes live load to Col. C3.

In constructing for each track the influence line for load at Col. C3, consider one pound on each floor beam at the center line of track. In case only one rail bears on the floor beam, consider one-half pound on the rail. The amount that reaches the Col. C3 from each floor beam can be obtained analytically or graphically. The latter method is used here.

The several sets of light lines numbered 1 to 9 (see Plate 1) divide each group of floor beams, and also each of the girders into ten equal spaces. This makes it possible to read directly the decimal part of each unit load on each floor beam that reaches the girder, and also the decimal part of each floor beam or panel load that reaches the column.

As an illustration, we will consider 1 pound on floor beam No. 12 at center line of track No. 1. The center line of track No. 1 intersects the floor beam No. 12 between light lines No. 2 and No. 3, the exact position being estimated at 2.65; as the floor beam is divided into ten equal parts, .265 pounds will be the amount distributed to the girder G13 at floor beam No. 12. This is tabulated in line No. 2 under floor beam No. 12 in the table for track No. 1 on page 17. Floor beam No. 12 connects to girder G13 between light lines No. 4 and No. 5, the exact position being estimated at 4.65. As the girder is divided into ten equal spaces, 4.65 times the floor beam or panel load at panel point No. 12 reaches the Col. C3. This is tabulated in line No. 3 under floor beam No. 12 in the table for track No. 1 on Plate 2.

It will be noticed that the items in line No. 3 are the same for all tracks except at floor beams No. 10, where the latter do not connect to the girder directly opposite each other.

The decimal part of a pound that is distributed to Col. C3 from unit load at center of track No. 1 and floor beam No. 12 is equal to the product of lines No. 2 and No. 3 and is shown in line No. 4 under floor beam No. 12 in table for track No. 1 on Plate 2.

The results for each track, floor beam, etc., are tabulated on Plate 2. The decimal parts of a pound tabulated in line No. 4 are the ordinates for constructing the influence lines on Plate 3.

The given wheel loads should be spaced on a strip of paper to the same scale as figure on Plate 1.

A maximum live load at Col. C3 is produced by placing one of the heavy wheels at the floor beam from which unit load produced a peak in the influence line. More than one trial may be necessary.

The ordinates measured at each wheel multiplied by the weight of the wheel gives the column load produced when that wheel is on its respective floor beam and track.

For example: The ordinate in the influence line for track No. 1 wheel No. 10 is .046, wheel load No. 10 = 27,500 pounds. Live load to Col. C3 from wheel No. 10 on track No. 1 = .046 × 27,500 = 1,200 pounds. (See Plate 4.)

The sum of these loads for all wheels on each track gives the maximum total live load to Col. C3.

The ordinates, loads, etc., for each track are shown in the summary on Plate 4.

GENERAL METHOD FOR DRAWING INFLUENCE LINES FOR STRESS IN A SIMPLE TRUSS.

The method is general in its application to both moment and stress influence lines. The truss may be of any shape and the loads may be applied to either the upper or lower chord joints.

As for analytical calculations, a section is passed through the truss cutting the member whose influence line is to be drawn. This section also cuts the stringers in the panel containing the loaded chord cut by the section.

To draw the influence line, let

L = length of span.

d = length of "cut stringer."

b = distance from the left support of the truss to the left end of the cut stringer.

s = distance from the left support of the truss to the center of moments.

t = distance from the right support of the truss to the center of moments.

r = perpendicular distance from center of moments to member whose influence line is being drawn.

w = total load on span.

w_1 = total load on panels to left of cut stringer.

w_2 = total load on cut stringer.

w_3 = total load on panels to right of cut stringer.

P = concentrated load at the joint on which unit load produces a maximum stress in the member considered.

I. Draw the truss diagram to any scale. (See following plates showing various types which are lettered the same for corresponding points.) Locate the center of moments for the member whose influence line is to be drawn.

II. Draw verticals through the center of moments, the left support, the right support, the left end of the cut stringer, and the right end of the cut stringer.

III. Lay off on the vertical through the left support, to any scale, the distance CD equal to $\frac{s}{r}$.

IV. Draw a horizontal line through D intersecting the vertical through the right support at B.

V. Draw a straight line through B and C cutting the vertical through the center of moments at O and cutting the vertical through right end of the cut stringer at F.

VI. Draw a straight line through O and D cutting the vertical through the left end of the cut stringer at E and the vertical through the right reaction at H.

In case it is inconvenient to locate the point O, the point E may be found by drawing the line DH. The distance BH being equal to $\frac{t}{r}$.

VII. Connect E and F and the shaded polygon DEFBD is the stress influence line desired. Any ordinate between the line DEFB and the line DB is the stress for a unit load on the truss of the point vertically above the ordinate.

The total stress for any system of vertical loads is equal to the algebraic sum of the products of the loads and their respective ordinates in the stress influence polygon.

In case the moment about any center of moments is desired, the construction of a moment influence line is the same as that of a stress influence line except that the distances CD and BH are respectively equal to s and t.

Stress influence lines for web members of a truss having parallel chords may be constructed by this method. In this case the distances s and t become infinity and the distances CD and BH become unity for vertical members and unity times the secant of Φ for inclined members. (See Plate 11.)

To prove the truth of the foregoing construction, write the general equation for the stress for W_1, W_2 and W_3 equal to unit loads. It will then be seen that the equation thus found will coincide with the stress influence line as described.

In the preparation of these notes on the use of influence lines, valuable suggestions were obtained from the following books, which may be consulted for proofs and a more complete study of the subject. Reference:

Modern Framed Structures, Johnson, Bryan and Turneaure; Influence Diagrams, M. A. Howe; Roofs and Bridges, Merriam, Jacoby; Framed Structures and Girders, Edgar Marburg; The Theory of Structures, C. M. Spofford; Structural Engineering, J. E.

Kirkham; Das Verfahren der Einflusslinien, Th. Landsberg; Design and Construction of Metallic Bridges, Burr and Falk; The Graphic Method by Influence Lines for Bridge and Roof Computations, Burr and Falk.

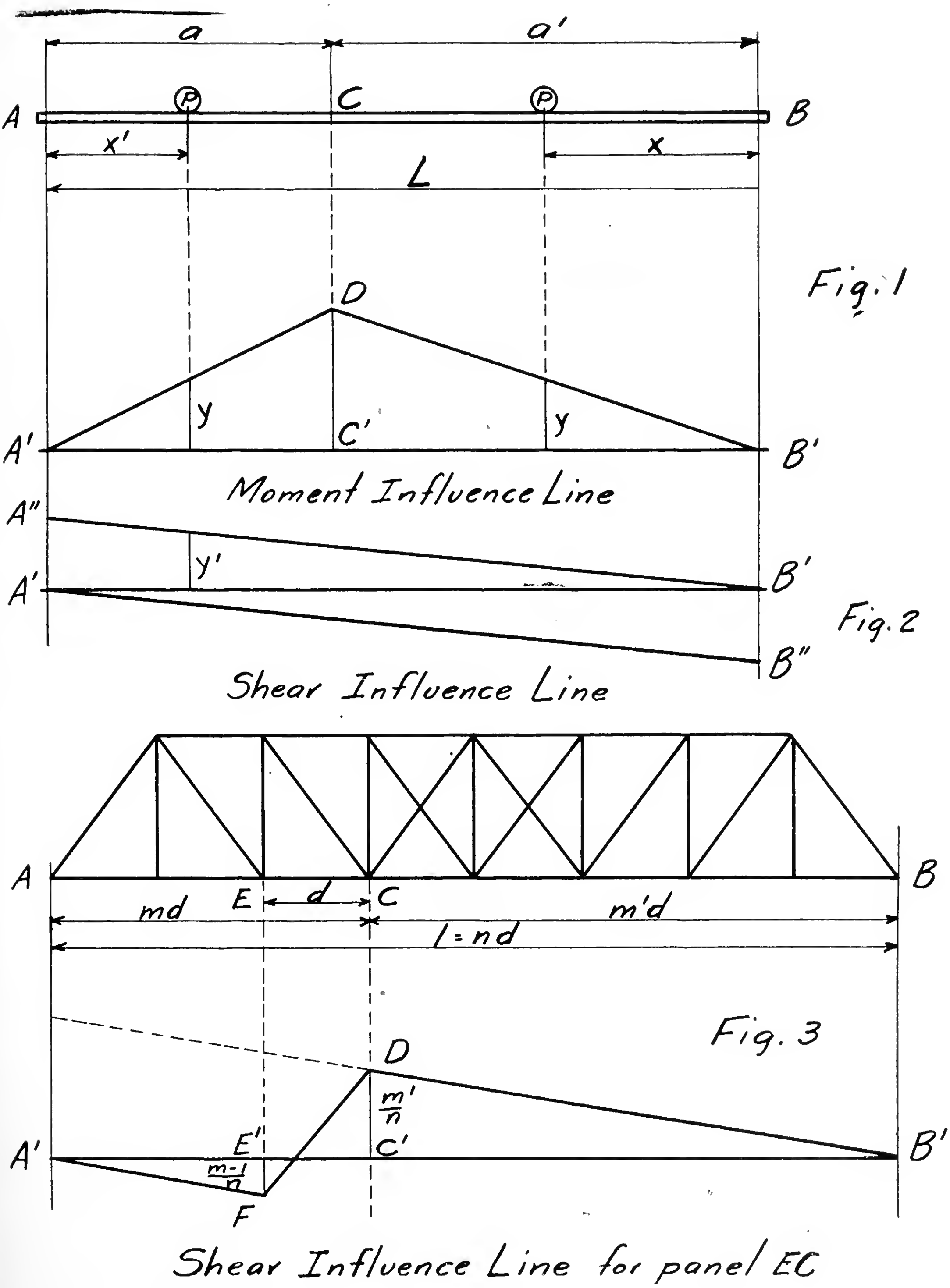


Plate A.

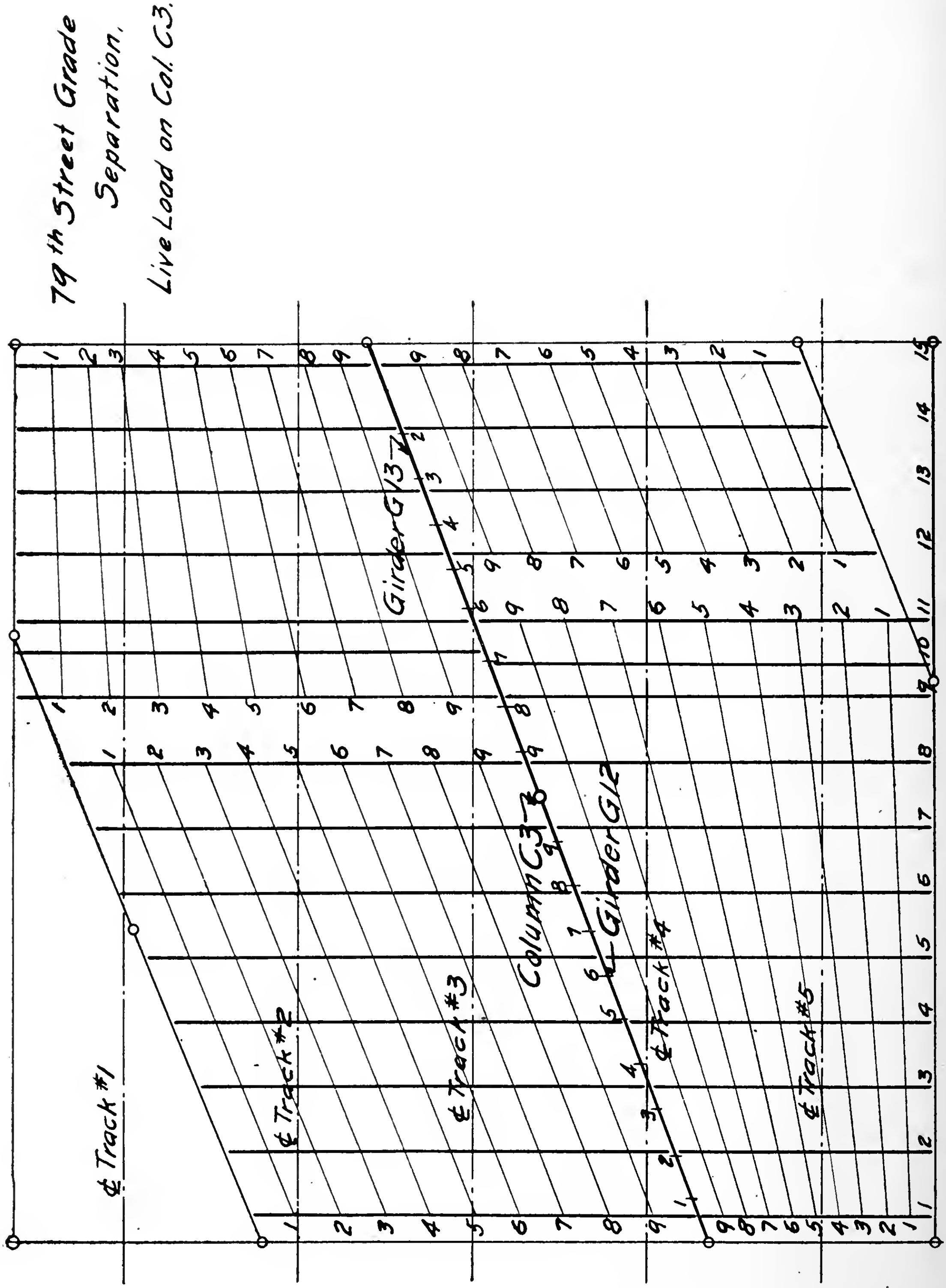

79 th Street Grade Separation.
Live Load on Col. C3.
Girder G13
Column C3
Girder G12
℄ Track #1
℄ Track #2
℄ Track #3
℄ Track #4
℄ Track #5

Plate 1.

Table for Track #1.

1	Floorbeam No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	% to G12 or G13.	—	—	—	—	—	.040	.070	.122	.230	.235	.245	.265	.280	.305	.325
3	% to Col. C3.	—	—	—	—	—	.790	.935	.925	.780	.685	.610	.465	.320	.180	.045
4	Total to Col. C3.	—	—	—	—	—	.032	.065	.113	.180	.161	.149	.123	.090	.055	.015

Table for Track #2.

1	Floorbeam No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	% to G12 or G13	.100	.160	.220	.275	.335	.390	.460	.515	.590	.620	.635	.675	.720	.770	.825
3	% to Col. C3	.060	.210	.355	.490	.640	.790	.935	.925	.780	.686	.610	.465	.320	.180	.045
4	Total to Col. C3	.006	.034	.078	.135	.215	.308	.430	.477	.460	.425	.387	.314	.231	.139	.037

Table for Track #3.

1	Floorbeam No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	% to G12 or G13	.480	.540	.595	.660	.715	.770	.825	.880	.960	.985	.980	.925	.870	.815	.750
3	% to Col. C3	.060	.210	.355	.490	.640	.790	.935	.925	.780	.685	.610	.465	.320	.180	.045
4	Total to Col. C3	.029	.113	.211	.324	.458	.608	.771	.814	.748	.675	.598	.430	.278	.147	.039

Table for Track #4.

1	Floorbeam No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	% to G12 or G13	.860	.915	.975	.960	.880	.820	.760	.715	.665	.645	.620	.535	.475	.425	.365
3	% to Col. C3	.060	.210	.355	.490	.640	.790	.935	.925	.780	.716	.610	.465	.320	.180	.045
4	Total to Col. C3	.052	.192	.346	.471	.563	.648	.710	.662	.519	.461	.378	.249	.152	.077	.016

Table for Track #5.

1	Floorbeam No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	% to G12 or G13	.515	.455	.410	.375	.345	.320	.300	.280	.265	.255	.245	.140	.080	.047	.019
3	% to Col. C3	.060	.210	.355	.490	.640	.790	.935	.925	.780	.715	.610	.465	.320	.180	.045
4	Total to Col. C3	.031	.096	.145	.184	.221	.253	.281	.259	.207	.182	.150	.065	.026	.008	.001

Lines 2 give % of 1 pound at centre of track which is distributed by each floorbeam to girders G12 or G13.

Lines 3 give % of 1 pound at end of each floorbeam on girders G12 or G13 which is distributed to column C3.

Lines 4 give % of 1 pound at centre of track on each floorbeam which is distributed to column C3.

Plate 2.

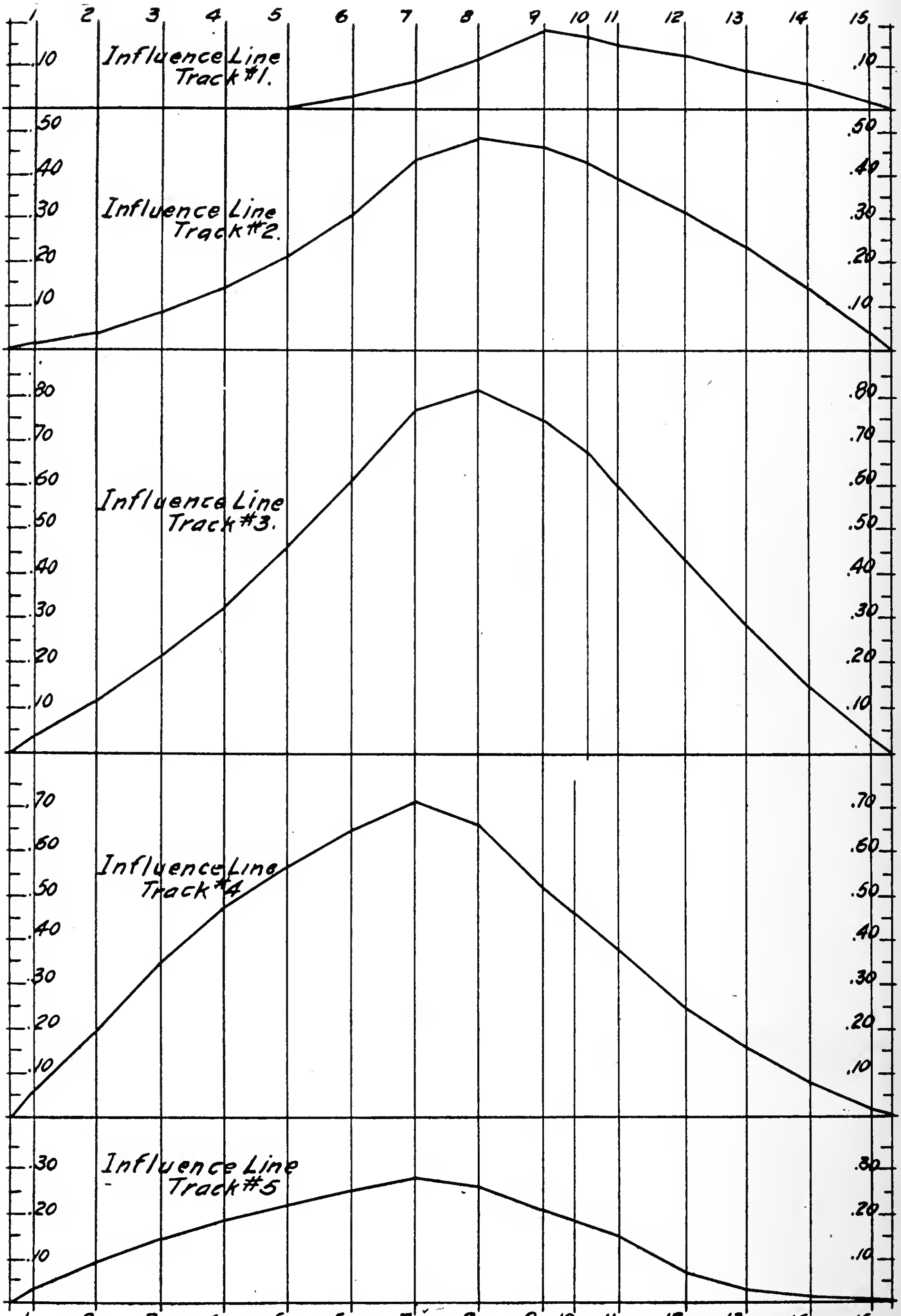

Influence Line Track #1.
Influence Line Track #2.
Influence Line Track #3.
Influence Line Track #4
Influence Line Track #5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Plate 3.

Live Load on Column C3.
Cooper's E55 Loading on each track.

Wheel No.	Wheel Load	Track #1 Ord.	Track #1 Load	Track #2 Ord.	Track #2 Load	Track #3 Ord.	Track #3 Load	Track #4 Ord.	Track #4 Load	Track #5 Ord.	Track #5 Load
6	35750	—	—	.003		—	—	—	—	—	—
7	"	—	—	.026	8400	.025		—	—	—	—
8	"	—	—	.073		.112	12400	.050	8600	.032	4500
9	"	—	—	.133		.210		.190		.095	
10	27500	.046	1200	.256	7000	.390	10700	.405	11100	.165	4500
11	55000	.122		.433		.615		.570		.222	
12	"	.180	32300	.477	97800	.771	162200	.650	142700	.254	55900
13	"	.155		.460		.814		.710		.281	
14	"	.130		.408		.750		.664		.260	
15	35750	.070		.278		.520		.441		.174	
16	"	.035	3800	.189	19900	.370	41400	.320	37700	.112	12300
17	"	.003		.075		.195		.190		.042	
18	"	—	—	.015		.072		.105		.015	
Unif.	5500	—	—	—	—	—	—	.005	400	—	—
Load	per ft.	—	—	—	—	—	—	.003		—	—
			37300		133100		226700		200500		77200

Total Live Load to Column C3 equals
37300+133100+226700+200500+77200 = 674800.

Plate 4.

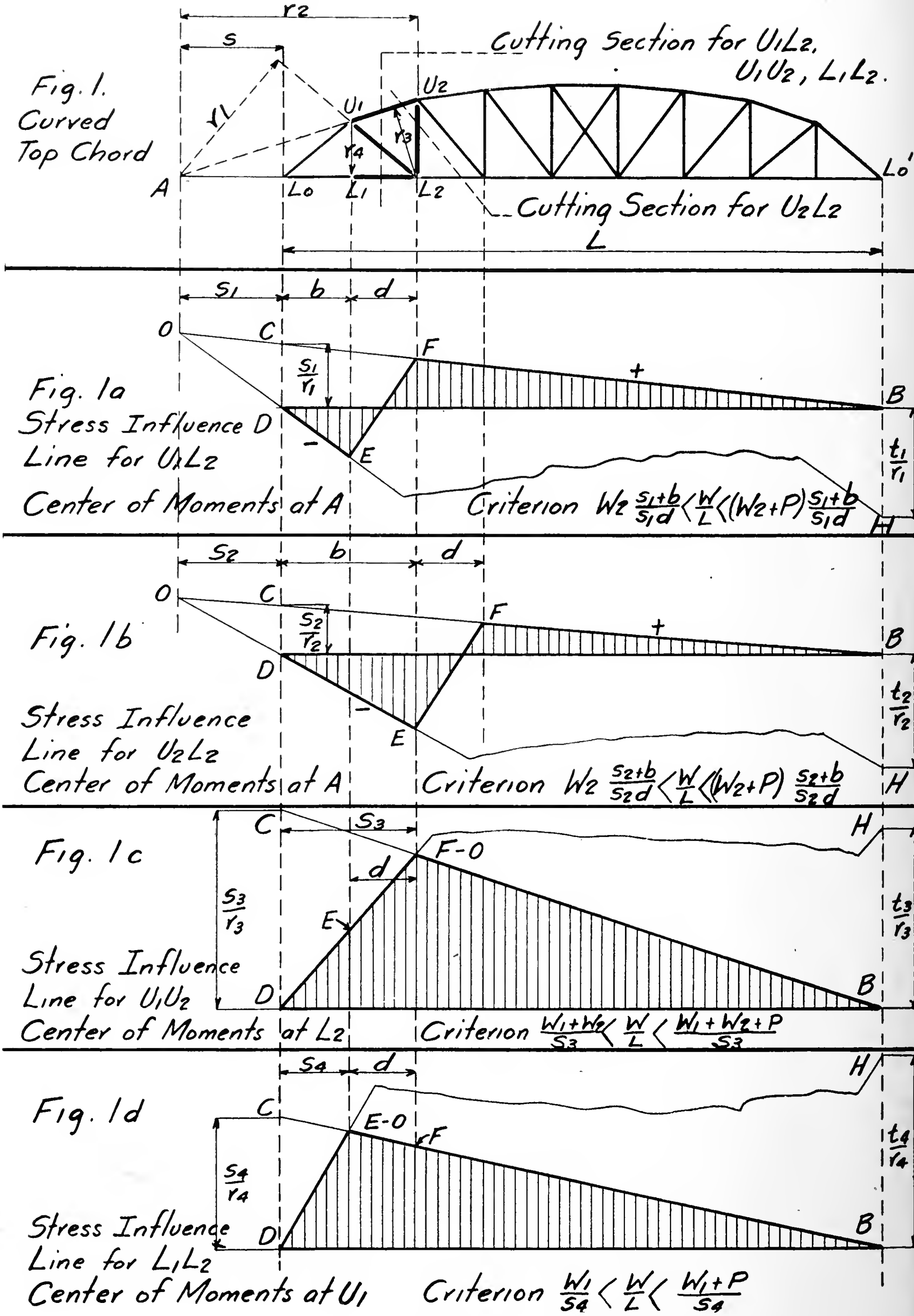


Fig. 1.
Curved
Top Chord
Cutting Section for U1L2,
U1U2, L1L2.
Cutting Section for U2L2
Fig. 1a
Stress Influence
Line for U1L2
Center of Moments at A
Criterion W2 (s1+b)/(s1d) < W/L < (W2+P) (s1+b)/(s1d)
Fig. 1b
Stress Influence
Line for U2L2
Center of Moments at A
Criterion W2 (s2+b)/(s2d) < W/L < (W2+P) (s2+b)/(s2d)
Fig. 1c
Stress Influence
Line for U1U2
Center of Moments at L2
Criterion (W1+W2)/s3 < W/L < (W1+W2+P)/s3
Fig. 1d
Stress Influence
Line for L1L2
Center of Moments at U1
Criterion W1/s4 < W/L < (W1+P)/s4

Plate 5.

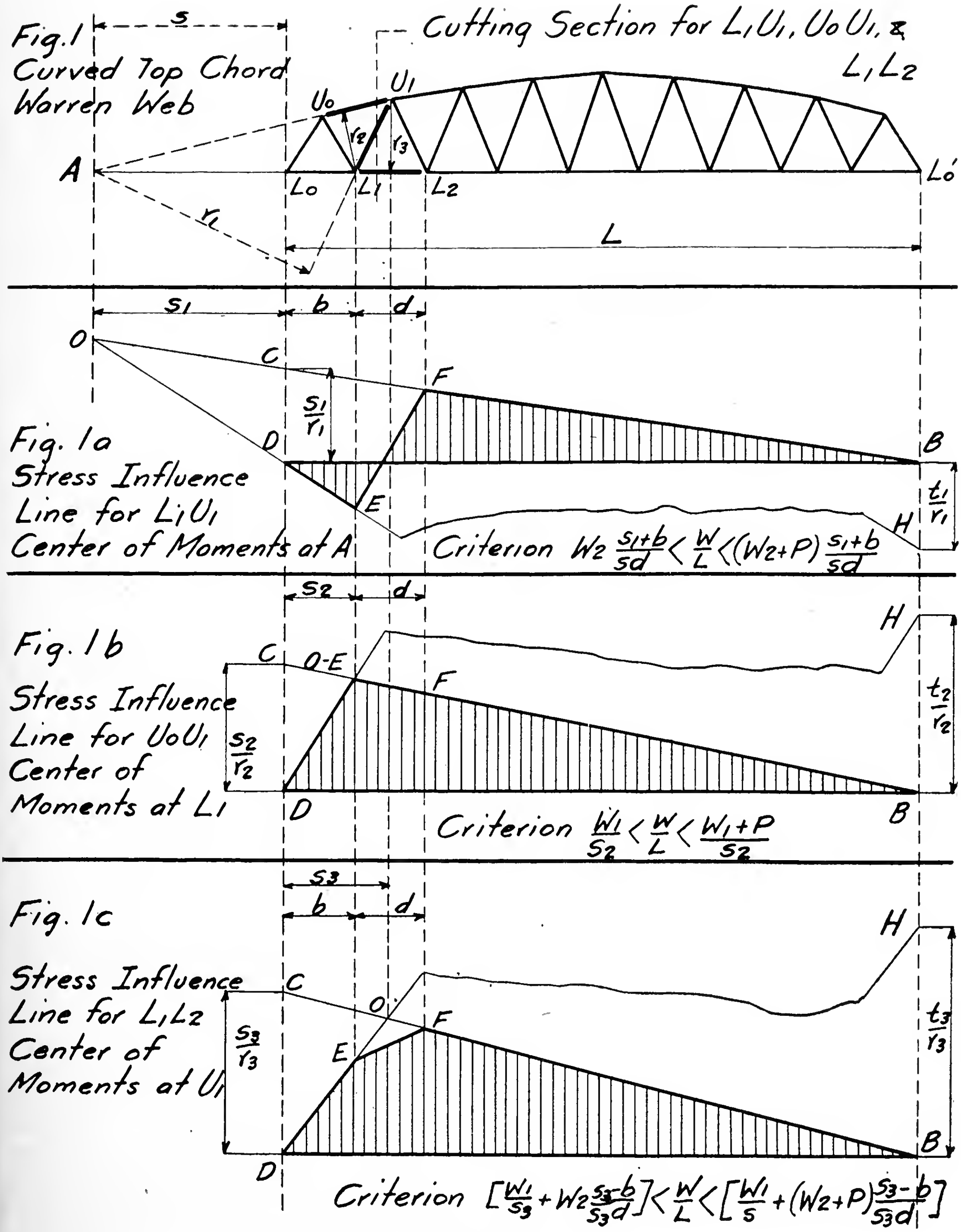
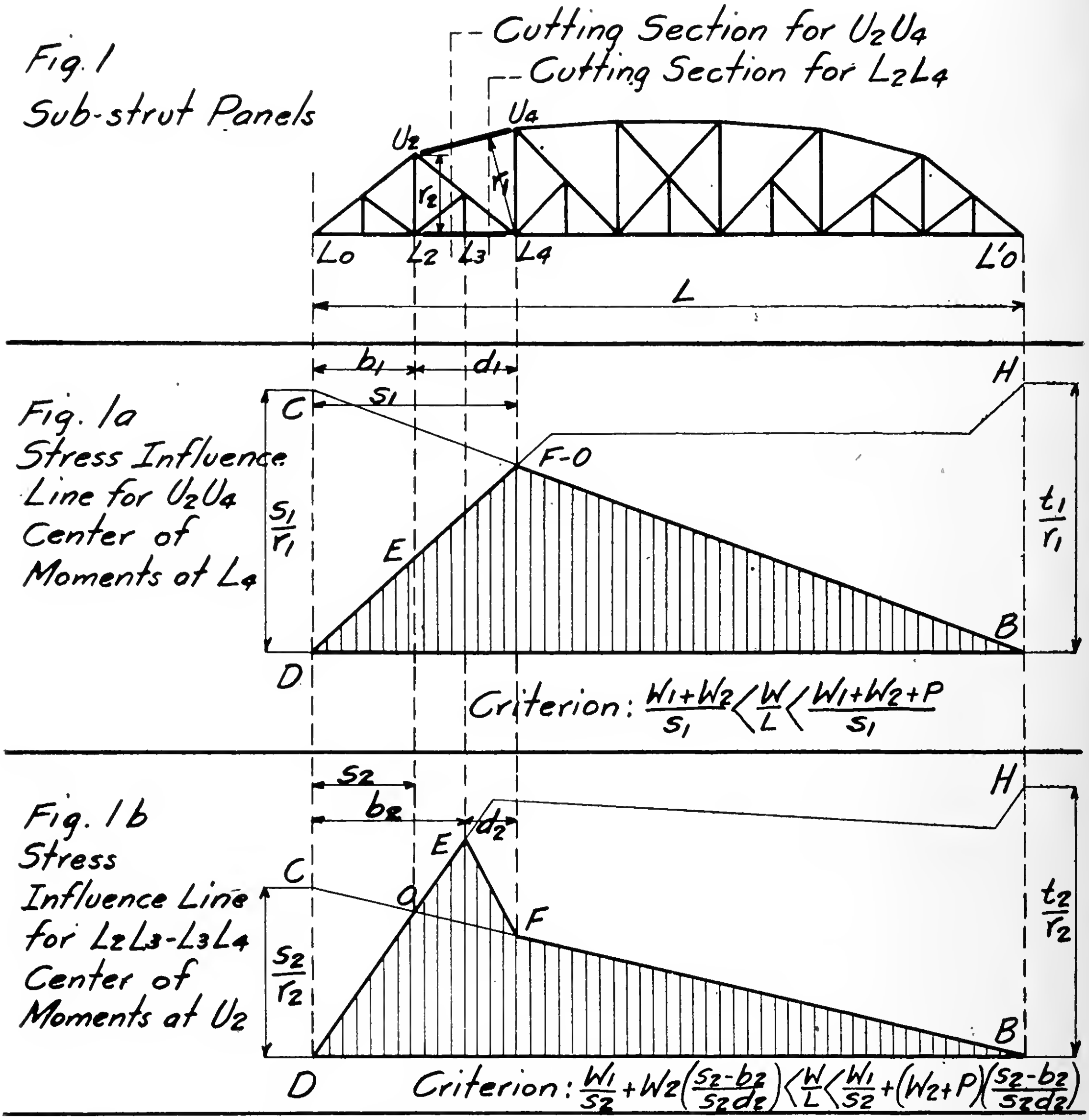


Fig. 1
Curved Top Chord
Warren Web
Cutting Section for L1U1, U0U1, & L1L2
s
A
U0
U1
r1
r2
r3
L0
L1
L2
L0'
L
s1
b
d
O
C
F
s1/r1
Fig. 1a
Stress Influence
Line for L1U1
Center of Moments at A
D
E
B
H
t1/r1
Criterion W2 (s1+b)/sd < W/L < (W2+P) (s1+b)/sd
s2
d
Fig. 1b
Stress Influence
Line for U0U1
Center of
Moments at L1
C
O-E
F
H
s2/r2
t2/r2
D
B
Criterion W1/s2 < W/L < (W1+P)/s2
s3
b
d
Fig. 1c
Stress Influence
Line for L1L2
Center of
Moments at U1
C
O
F
E
H
s3/r3
t3/r3
D
B
Criterion [W1/s3 + W2 (s3-b)/s3d] < W/L < [W1/s + (W2+P) (s3-b)/s3d]

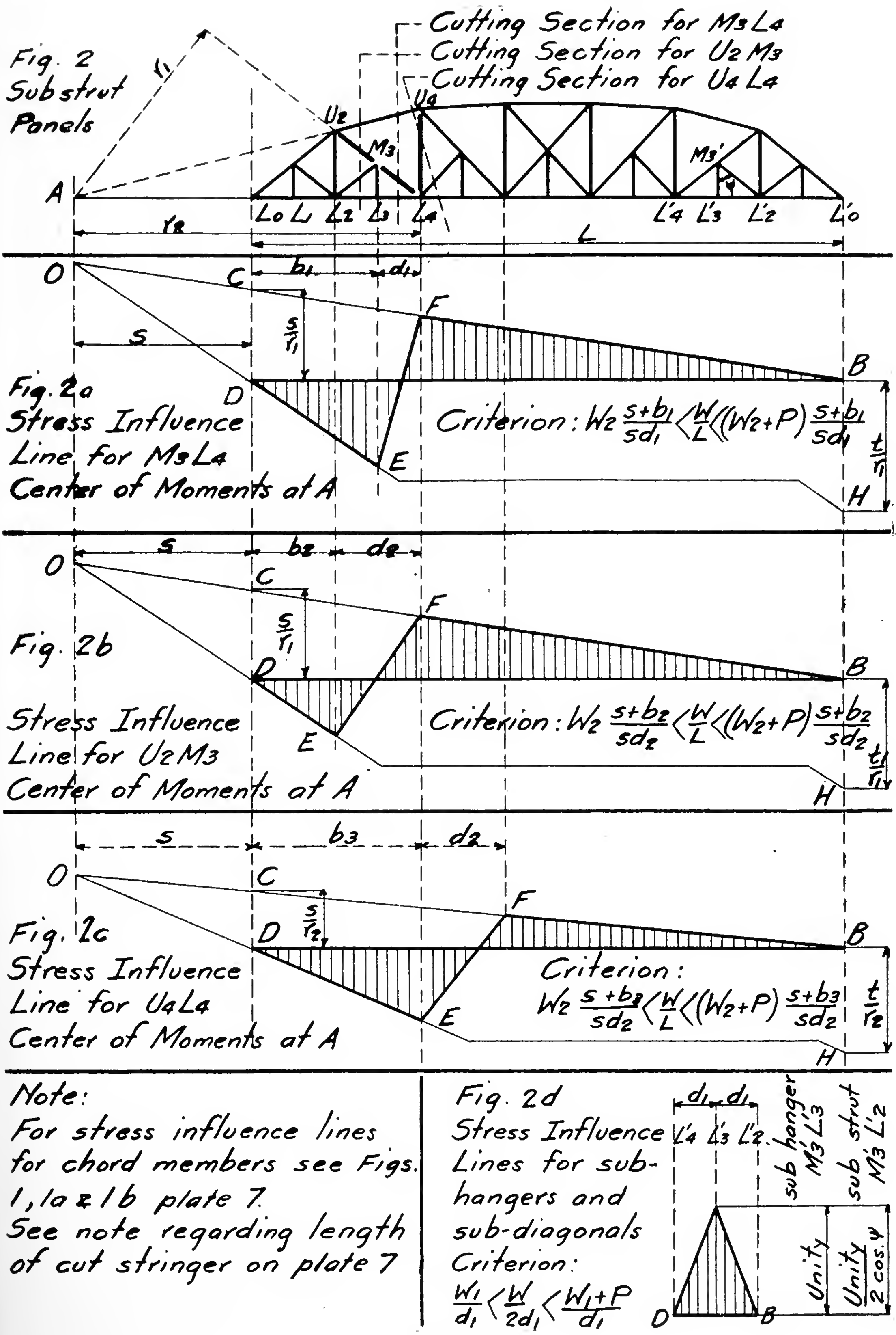
Plate 6.



Note: For stress influence lines for web members see Figs. 2, 2a, 2b, 2c, & 2d plate 8. In trusses with subdivided panels a subtruss is formed by the subhanger, adjacent section of main diagonal, adjacent chord and substrut. The substrut is redundant for members not in the subtruss.

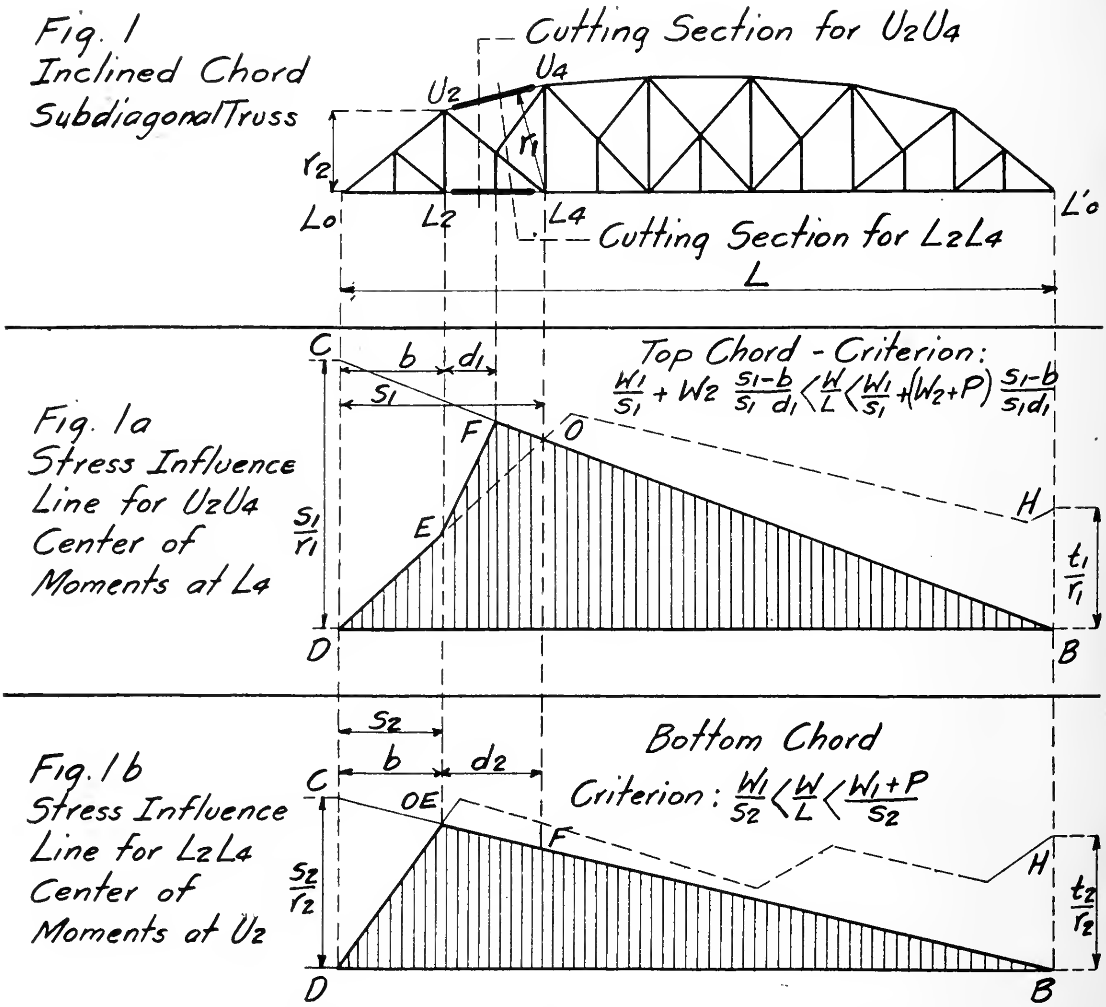
The cutting section, for any member not a part of the subtruss, cuts three other members including the substrut (redundant); the cut stringer length "d" is equal to the main truss panel length. The cutting section for a member, which is also a member of the subtruss, cuts but two other members; the cut stringer length "d" is equal to the subpanel length.

Plate 7.



Cutting Section for M3L4
Cutting Section for U2M3
Cutting Section for U4L4
Fig. 2 Substrut Panels
Fig. 2a Stress Influence Line for M3L4 Center of Moments at A
Criterion: $W_2 \frac{s+b_1}{sd_1} < \frac{W}{L} < (W_2+P) \frac{s+b_1}{sd_1}$
Fig. 2b Stress Influence Line for U2M3 Center of Moments at A
Criterion: $W_2 \frac{s+b_2}{sd_2} < \frac{W}{L} < (W_2+P) \frac{s+b_2}{sd_2}$
Fig. 2c Stress Influence Line for U4L4 Center of Moments at A
Criterion: $W_2 \frac{s+b_3}{sd_2} < \frac{W}{L} < (W_2+P) \frac{s+b_3}{sd_2}$
Note: For stress influence lines for chord members see Figs. 1, 1a & 1b plate 7. See note regarding length of cut stringer on plate 7
Fig. 2d Stress Influence Lines for sub-hangers and sub-diagonals
Criterion: $\frac{W_1}{d_1} < \frac{W}{2d_1} < \frac{W_1+P}{d_1}$
sub hanger M3'L'3
sub strut M3'L'2
Unity
Unity / 2 cos. ψ

Plate 8.



Note: For stress influence lines for web members see Figs. 2, 2a, 2b, 2c, & 2d plate 10. In trusses with subdivided panels a subtruss is formed by the subhanger, adjacent section of main diagonal, adjacent chord and subdiagonal. The subdiagonal is redundant for members not in the subtruss.

The cutting section, for any member not a part of the subtruss, cuts three other members including the subdiagonal (redundant); the cut stringer length "d" is equal to the main truss panel length. The cutting section for a member, which is also a member of the subtruss, cuts but two other members; the cut stringer length "d" is equal to the subpanel length. In a subdiagonal truss the main verticals receive stress from the subtruss and the cut stringer length "d" is equal to the sub panel length.

Plate 9.

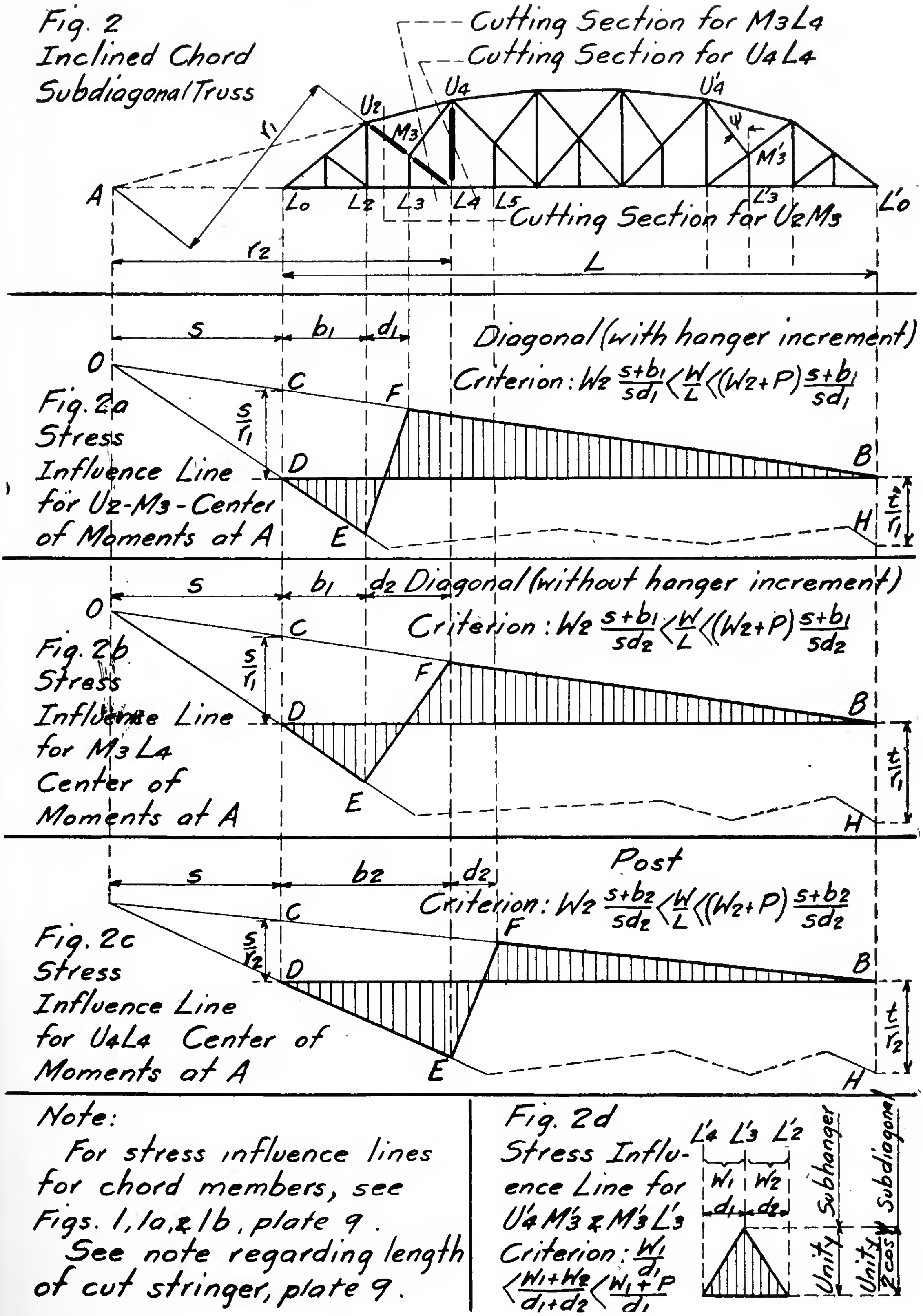


Fig. 2
Inclined Chord
Subdiagonal Truss
Cutting Section for M3L4
Cutting Section for U4L4
Cutting Section for U2M3
A
U2
M3
U4
U'4
M'3
L0
L2
L3
L4
L5
L'3
L'0
r1
r2
L
s
b1
d1
Diagonal (with hanger increment)
Criterion: $W_2 \frac{s+b_1}{sd_1} < \frac{W}{L} < (W_2+P)\frac{s+b_1}{sd_1}$
Fig. 2a
Stress
Influence Line
for U2-M3-Center
of Moments at A
O C D E F B H
$\frac{s}{r_1}$
$\frac{t}{r_1}$
s
b1
d2
Diagonal (without hanger increment)
Criterion: $W_2 \frac{s+b_1}{sd_2} < \frac{W}{L} < (W_2+P)\frac{s+b_1}{sd_2}$
Fig. 2b
Stress
Influence Line
for M3L4
Center of
Moments at A
O C D E F B H
$\frac{s}{r_1}$
$\frac{t}{r_1}$
s
b2
d2
Post
Criterion: $W_2 \frac{s+b_2}{sd_2} < \frac{W}{L} < (W_2+P)\frac{s+b_2}{sd_2}$
Fig. 2c
Stress
Influence Line
for U4L4 Center of
Moments at A
C D E F B H
$\frac{s}{r_2}$
$\frac{t}{r_2}$
Note:
For stress influence lines for chord members, see Figs. 1, 1a, & 1b, plate 9.
See note regarding length of cut stringer, plate 9.
Fig. 2d
Stress Influence Line for
U'4M'3 & M'3L'3
Criterion: $\frac{W_1}{d_1} < \frac{W_1+W_2}{d_1+d_2} < \frac{W_1+P}{d_1}$
L'4 L'3 L'2
W1 W2
d1 d2
Unity Subhanger
$\frac{\text{Unity}}{2\cos\psi}$ Subdiagonal

Plate 10.

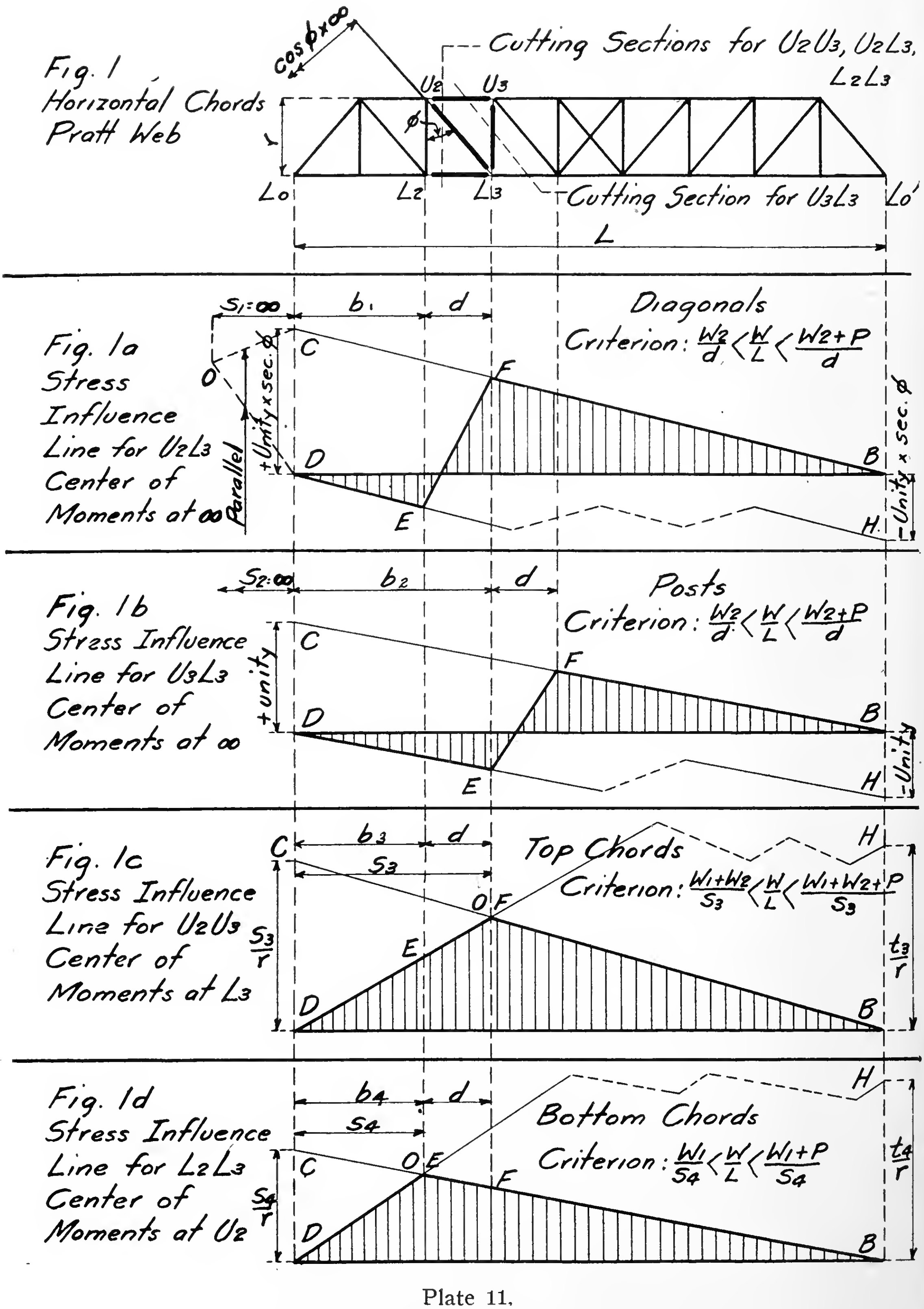


Fig. 1
Horizontal Chords
Pratt Web
Cutting Sections for U2U3, U2L3, L2L3
Cutting Section for U3L3
L0
L2
L3
L0'
U2
U3
L
Fig. 1a
Stress
Influence
Line for U2L3
Center of
Moments at ∞
Diagonals
Criterion: W2/d < W/L < (W2+P)/d
Fig. 1b
Stress Influence
Line for U3L3
Center of
Moments at ∞
Posts
Criterion: W2/d < W/L < (W2+P)/d
Fig. 1c
Stress Influence
Line for U2U3
Center of
Moments at L3
Top Chords
Criterion: (W1+W2)/S3 < W/L < (W1+W2+P)/S3
Fig. 1d
Stress Influence
Line for L2L3
Center of
Moments at U2
Bottom Chords
Criterion: W1/S4 < W/L < (W1+P)/S4

Plate 11.

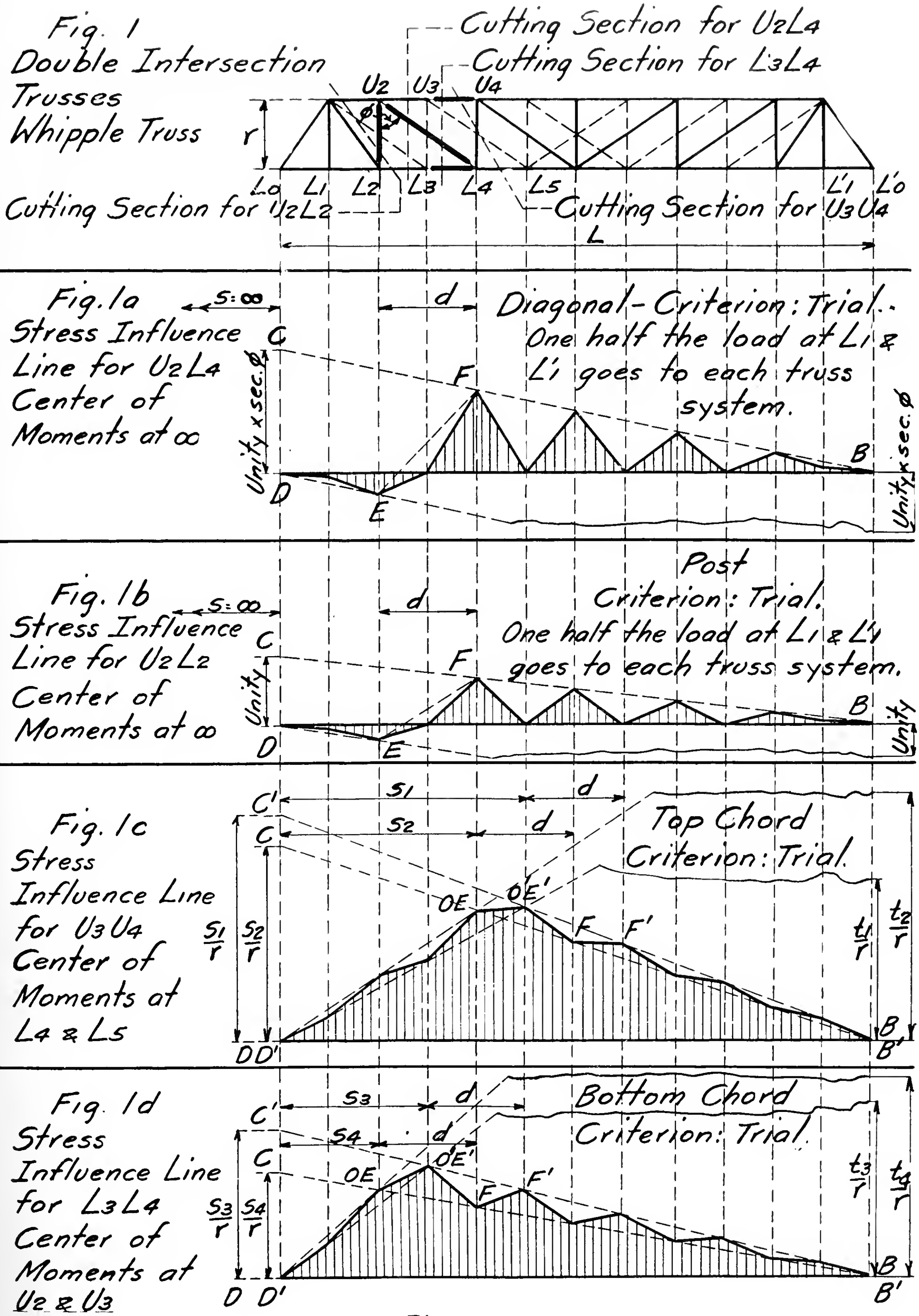


Fig. 1
Double Intersection Trusses
Whipple Truss
Cutting Section for U2L4
Cutting Section for L3L4
Cutting Section for U2L2
Cutting Section for U3U4
Fig. 1a
Stress Influence Line for U2L4
Center of Moments at ∞
Diagonal - Criterion: Trial.
One half the load at L1 & L'1 goes to each truss system.
Fig. 1b
Stress Influence Line for U2L2
Center of Moments at ∞
Post Criterion: Trial.
One half the load at L1 & L'1 goes to each truss system.
Fig. 1c
Stress Influence Line for U3U4
Center of Moments at L4 & L5
Top Chord Criterion: Trial.
Fig. 1d
Stress Influence Line for L3L4
Center of Moments at U2 & U3
Bottom Chord Criterion: Trial.

Plate 12.

DISCUSSION.

Albert Reichmann, M. W. S. E.: The use of a Williot's diagram for the purpose of finding the proper height of camber blocking during erection is fully described in the paper. But there is another use of such a diagram, which should be mentioned, and that is in the finding of the secondary stresses in any structure, if it is thought necessary to do so. All secondary stress calculations are based on the general relation between the end moment of a bent beam and the deflection angles at the two ends.

For practical application the best way is that proposed by Prof. Otto Mohr. He makes use of the angle through which any member turns from its unstressed position to its final position under stress. This angle is obtained from a Williot's diagram in this way:

Scale off the movement of one end of a member in reference to the other end and normal to the member itself; divide this distance by the length of the member and the quotient is equal to the sought angle.

Thus, referring to Plate 6 on Page 18, the dotted line U2-U2 represents the movement of U2 in reference to L3 normally to the member U2-L3. Dividing by the length of U2-L3 we get the angle of turning of said member. Having this angle and knowing the structural elements of each member, we can find, through a number of successive approximations, first, the angle of turning of each panel point, and second, the bending moment at the end of each member at each panel point.

This is a very convenient method, which can be carried out to any degree of accuracy. Of course, it is based on the general assumption that the deflection of the various panel points of a truss is the same, whether there are frictionless joints, as assumed in a Williot's diagram or riveted ones as generally carried out in practice.

I. F. Stern, M. W. S. E.: Matters of this kind ought to be in the Journal of the Society, as they are matters of engineering interest and contain information valuable to those who can make use of it, and therefore, the Society is to be congratulated upon having papers of this kind presented before it.

I do not want to get into any deep discussion of this matter, for I think it has been well presented, but I do not want to tell a story that came into my mind which may be of interest and possibly have some bearing upon this matter of the use of influence lines for calculating stresses. I will tell the story first and perhaps you may see its application:

Some time ago, when the question of scientific management and efficiency was first being talked about, they had the problem in Johnstown, Pennsylvania, of moving pig iron from one place to another most expeditiously. An efficiency man was called in and soon thereafter each man was moving two pieces of the pig iron where he had only moved one before. Of course, that was wonderful and everybody was happy. Finally, some one came along and

devised some machinery which moved the pig iron at a much cheaper unit rate than could possibly be accomplished by passing the pig from man to man under any possible development of scientific management.

I am afraid that many engineers have been so enthused about the use of influence lines that they have more or less lost sight of the fact that it is not necessary to use concentrated loads in any excepting possibly a small percentage of cases. In practically all cases, the effect of concentrated loads from an assumed engine loading, or from an engine in actual operation, may be determined with sufficient accuracy by the use of a uniform load over the entire structure with the addition of uniform excess load over a length equal to the driver wheel base.

In some recent work I have had to examine a great many bridges to decide on the work necessary to allow an especially heavy engine to run over a certain line. Several hundred bridges were in question, and an effort had to be made to do the work of computation in as short a time as was compatible with getting properly accurate results.

We figured many of the bridges by the absolute concentrated loads, by the use of influence lines and then figured the same bridges by the use of a uniform live load with a uniform excess over certain portions, and found the stresses came so closely alike by the two methods that we decided to use the latter method in all future computations, on account of the great saving in time.

Of course, after everything has been said and done, nothing can take the place of common sense and the seasoned computer must look over his figures after they have been made and see if they "look" right.

Really, the only point that I want to make is whether in devising methods to make calculations with certain fixed loads easier, are we not in danger of losing sight of the fact that it would be much simpler and easier and usually quite as accurate to use a uniform engine load with an excess over that portion occupied by the drivers.

A somewhat similar matter is brought out in the paper on the deflection of trusses where it was shown that for ordinary trusses, the Williot diagram showed that our old method of increasing the length of the top chord one-eighth inch in ten feet produces practically proper results.

F. G. Vent, M. W. S. E.: In line with what has just been said about the accuracy of using equivalent loads for wheel loads, I call to mind a case where I was called upon to figure the stresses in the 400 ft. span of the C. M. & St. P. Ry. at Randolph Bluffs, Mo. This bridge was a Whipple truss span and I calculated the stresses by first making an influence table and then applying an equivalent load consisting of a uniform load with two engine excess loads to compensate for the driver concentrations, using two certain excess loads

where moments governed and two other excess loads where shears governed, and found, upon a later investigation, that the stresses were within 1 per cent of actual.

This is quite an easy and rapid method to one who accustoms himself to its use and can be made a very accurate method at the same time. In the above case it took less than an hour to make the influence table and considerably less than a day to obtain the stresses and unit stresses accurately, within 1 per cent.

In regard to deflections, the question arises of what real value they are and when you are warranted in expending the time in figuring them and when are you not.

I believe, in the ordinary railroad span up to 200 ft. in length, that it is unnecessary to expend the time to figure deflections and that if a camber of, say 1/1200 to 1/1500 of the span is put into the trusses at the center and the chord pins placed on circular arcs, that the actual conditions will be hit more closely than by figuring the center deflection for simultaneous stresses with chord stress at the center a maximum. As an illustration, let us refer to the deflection diagrams shown this evening and we see that the panel points near the ends of the span lie on a flattened circle. This is because the deflections were figured for simultaneous stresses from a uniform load giving a maximum center moment. This loading will not show a full deflection for the panel points near the ends, just referred to, because the members there have enough sectional area to take a stress due to the wheels both in a position for maximum shear and for maximum moment, which positions give considerably larger stresses in the end web and chord members than the uniform load used in figuring the simultaneous stresses.

Therefore, the actual deflection near the ends of the span will be more than the "flattened circle" diagram shows.

It will be noted here that a true deflection diagram is an inverted diagram of the camber blocking, which should be used in erecting the span and that the lengths of the various truss members should be calculated to give the truss the shape it will take when on the camber blocking.

Now we can raise the camber blocking at any point or points between the center of the span and the ends to equal any actual deflection that may take place at such point or points without disturbing the height of the camber blocking which we have put at the center of the span to provide for the center deflection, which has been figured accurately, provided we calculate the lengths of the various members of the truss to correspond.

Therefore, to provide the proper camber blocking for the truss it will be necessary to place blocking at the center of span equal in height to the center deflection figured, and at points near the end of the span, blocking of the height of the actual deflection of the point considered, which will be greater than is shown at the "flattened circle" portions of the diagram in the paper.

To determine the exact heights of camber blocking which should be used at the various panel points of the truss, it will then be necessary to first determine the actual deflections at each panel point and make the various heights equal to the various deflections.

To do this it will be necessary to determine the simultaneous stresses occurring in the various members, while the maximum stress is occurring in each separate member, and then determine the deflections at the various panel points due to the various simultaneous stresses obtained.

This, of course, would be a very tedious operation, but, if done, it will be found that the actual deflection and camber diagrams will not be this "flattened circle" referred to, but very nearly a true parabola and the difference between the ordinates of this parabola and a true circular arc will be negligible. Hence a circular camber not only is more accurate but gives the various truss members more uniformity of length and saves time and labor in calculating their lengths.

The proper loading to use in calculating the deflections at each point is a uniform load with one or possibly two excess loads, which when shifted to the critical panel point will give the maximum deflection at the point; and it will be noted that when any one point is fully deflected all other points will be so nearly at the same level that all butt joints, etc., will be practically truly square while carrying their maximum load.

The question is often asked whether or not impact should be used in calculating deflections.

The object of cambering a truss is to have the truss level under full maximum load, with all butt joints, etc., perfectly square, so each member will take its maximum stress with no secondary or eccentric stress in the member, and if we use impact in designing the sections of the various members, we should of course use impact in calculating deflections because the impact is a part of the full maximum load the truss is to carry when fully deflected.

To provide for a possible use of the truss at some future time to carry maximum loads above those for which it was designed, the camber may be increased an amount, such that with full deflection under the loads for which it was designed, there will be a very small camber left in it, while under a possible future greater maximum load, the truss will deflect below the level portion an equally small amount. Thus, by allowing the truss to be overstressed slightly under full original loads, due to secondary eccentric stresses in the butt joints, etc., it will be capable of carrying a considerably greater possible future load, with a minimum amount of secondary eccentric stresses in the butt joints, etc.

I recently calculated for the American Bridge Company, the deflections and made Williot diagrams for the 296 ft. span of the Municipal Bridge of St. Louis. This span contained one truss carrying half of the railroad, a center truss carrying half of railroad

and half of highway and an outside truss carrying half the highway.

I found the maximum deflection of the outside highway truss to be $6\frac{13}{16}$ in. at the center point and of the panel point opposite, in the center truss, to be $4\frac{5}{8}$ in., these deflections occurring when both highway and railway are carrying maximum loads, and to make matters worse, the center truss will deflect much less without the train loads, while the highway truss at this point will still deflect $6\frac{13}{16}$ in. under full highway loading only, making the difference in deflection of these opposite panel points about $3\frac{1}{2}$ in. What will happen to the floorbeam connections with one end starting at $3\frac{1}{2}$ in. higher than the other end and ending at the same level during this deflection of trusses? The most that could be done would be to cut this $3\frac{1}{2}$ in. down to $1\frac{3}{4}$ in. by arranging the end connection elevations. The railway trusses were 55 ft. 0 in. deep and the highway truss 39 ft. $10\frac{1}{2}$ in. deep, center to center, of necessity, accounting for its great deflection.

I believe the sections should be increased in a case like the highway truss to cut down the deflection.

It points out the evil, however, of having a center truss in a bridge. They, of course, should be avoided where possible to use two trusses.

It also points out the evil of the span with a long skew, which throws panel points opposite each other which will have unequal deflections at the same time.

It will also show the necessity of figuring the deflections during the design of a span with two trusses, where, of necessity, one truss may be made shallower than the truss opposite. In this case the sections of the members of the shallow truss should be increased to make the deflections of the two trusses equal or as nearly so as practical conditions may demand.

In skew spans, such as the Rock Island-Western Indiana Crossing at 79th St., Chicago, unsymmetrical spans, or double intersection spans, the influence table affords the most practical method of determining quickly and accurately the stresses.

In the design of the draw span both the use of the influence table and the calculations of deflections are essential.

NAVAL PREPAREDNESS AND THE CIVILIAN ENGINEER

By Frank J. Sprague.*

Presented December 29, 1915, at a Joint Meeting of the Electrical Section, W. S. E., and Chicago Section, A. I. E. E.

There is one common ground on which all sane men can stand. We wish neither to kill or to be killed. Whether from one's own desire or at the command of someone else, we would not, under ordinary circumstances, willingly drill a hole through a fellow being with a ball or bayonet thrust, beat out his brains with a rifle butt, strangle him with poisonous gases, mangle him with shrapnel or high explosive shell, or blow him, individually or collectively, into fragments with hand grenade or mine. Aside from any humanitarian reasons affecting ourselves and those dependent upon us, such conduct violates our engineering sense, for it is not a promoter of human efficiency and is at least a wanton waste of what might be good material.

Because of appreciation of all this, but disregarding the lessons of history, we have the pacifist of the common garden variety, the neutral who is born neuter and would reduce all mankind to the same state of helpless impotency. But unhappily, the real world, with its widely varied peoples, forms of government, racial antipathies and national and commercial rivalries, has not yet arrived at that state of moral stature and mental equilibrium which can eliminate vital differences, or will permit their final reference to a common tribunal. We must face the facts of life as they are determined by forces still beyond our control and universal democracy as against autocracy must precede universal peace.

Therefore, for every man who cavils at the need of present military and naval preparedness, who places faith in our national safety upon the assumed impregnability of geographical isolation, the sacredness of treaties, the dogmas of religion, or upon that childlike conceit, a blind reliance upon some peculiar power of the fifty-seven varieties of Americans to rise superior to any emergency in times of great crisis, a calm and dispassionate review of the events of the past seventeen months and the present status of the countries at war may not be amiss. And if this be supplemented with a brief summary of the growth and career of the United States Navy, the attitude of the country and politicians at various times with regard to it and the part played by civilians in its unbuilding, perhaps some well-needed lessons may be taken to heart at a time of what seems to me may prove a great national crisis.

*Member, Naval Consulting Board of the United States.

A REVIEW OF THE GREAT WAR.

On June 28th, 1914, the heir presumptive of the Austrian throne, Franz Ferdinand, and his consort were assassinated at Serajevo. Investigation by the Austrian authorities indicated, and probably truly, that this crime was not the work of an individual but was the result of a plot in a large measure instigated with the connivance of certain Servian military officials. The actual perpetrators of the crime were punished, and for the time it seemed as if no grave international complications would result, but after a period of quiet there was suddenly presented to the Servian Government on July 23rd an ultimatum acceptance of which was demanded within forty-eight hours.

With what followed you are all familiar, although of what almost certainly passed between Austria and her ally in that particularly critical period there seems to be no public record. But it seems fair to assume that Austria had determined to put an end to plotting against her sovereignty, by an ultimatum which, if accepted, meant making Servia practically a vassal state, and if not, as was probably expected, would warrant military punishment and conquest; and that in this attitude she had the full advice and support of her ally.

The response by Servia being declared unsatisfactory, on July 28th Austria declared war against her. Immediately followed the mobilization of Russia, championing Servia, then of Germany and France, while the rulers and diplomatists of the various European Governments vainly discussed the possibilities of preventing a world war.

On the evening of August 1, Germany, on the nominal score of Russia's preparations, declared war with that country, and on the same day the Grand Duchy of Luxembourg was entered by German troops. Two days later war was declared against France, and Belgium, having refused free passage to German troops and on that account being declared an enemy, was invaded on the 4th of August, when a small body of Germans demanded the surrender of Liege.

On the same day a peremptory notice by England demanded respect of Belgian neutrality by Germany, with the alternative of a call for the passports of the British Ambassador and the taking of all necessary steps to compel the observance of a treaty to which both countries were parties. Since no adequate response to this demand was forthcoming, this demand for passports practically amounted to a declaration of war. On the same day Italy announced that as Germany had declared her war aggressively, she was not bound by the agreement of the Triple Alliance and would remain neutral.

The full report of the British Ambassador in Berlin under date of August 8th is remarkable for its indication of the line of German thought and, to a considerable extent, the military plan of the

Empire, which was based upon the necessity of striking France in the quickest and most overwhelmingly possible manner and hence by the easiest route. It is also important as evidence of the grave concern which was felt by Germany with regard to England's action, and explains much of the present intensity of feeling in that quarter. On the 6th of the month, Austria had declared war against Russia, and on the 13th England responded with a like declaration against Austria, thus completing the original setting for the Great War.

The march of military events on land proceeded swiftly, but in spite of Germany's remarkable state of preparedness and the thoroughness and efficiency of her organization, the valiant resistance of Belgium delayed, and to an appreciable extent checked the German avalanche, giving the British and French an opportunity to organize for a more effective defence. But the march on Paris seemed irresistible, and there was a constant retreat of the Allied forces, as fort after fort was crushed and city and town were occupied. But a month after the invasion of Belgium, the German forces, within 25 miles of Paris, were on the 6th and 7th of September suddenly checked and forced back in the Battle of the Marne, a retreat and battle which will probably go down as one of the most famous in history. That was nearly sixteen months ago, since which time the whole Western front, from the English Channel to the Jura Mountains, a distance of approximately three hundred miles, has been rigidly held against any further advance, and gains on either side for even the shortest distances have been accomplished only with fearful sacrifices.

Into the details of the operations on land, whether on the western, eastern or southern fronts, and the German successes on the latter, or the purposes of the moves toward Egypt and India I shall not here enter, but only touch very briefly upon that which is of perhaps even greater present moment to us—the operations at sea.

Immediately preceding the beginning of the war, a powerful naval fleet had been mobilized for the annual manoeuvres in Great Britain's home waters, which, because of an apparent scenting of danger by Winston Churchill, had on his own initiative and responsibility been held intact pending the negotiations between the Great Powers following the Austrian ultimatum to Servia. Its presence would guarantee France against assault from the sea on her northern coast, and would leave her fleet free for operations in the Mediterranean or elsewhere.

War having been declared, it was incumbent upon the English fleet to guard its own shores and the Channel coast of France from invasion, protect the movements of its troop-ships and commercial marine, to destroy or effectively bottle up the German fleet, and to clear the seas of enemy raiders and commerce, as well as protect the landing of troops and reduce land fortifications when possible. We need not concern ourselves with more than a brief outline of

its activities, but before long it gave ample demonstration of its world-wide power. Naval hostilities began almost immediately with a flotilla engagement in the North Sea on the 5th of August. Following several minor engagements, on August 28th occurred the action off Heligoland, in which the British fleet were victorious, but as against this success may be counted the sinking of many merchantmen by the fast German cruisers, Dresden, Emden and Carlsruhe.

The early torpedoing by German submarines of the British Cruiser Pathfinder, and then of the Aboukir, Cressy and Hogue within a few minutes of each other, came like a bolt from a clear sky, and promised to verify the prediction of the coming supremacy of the submarine by the famous British Admiral, Sir Percy Scott, whose professional standing is evidenced by the adoption of his system of fire control by the British Navy.

The British Admiralty's order was to seek out and destroy the German fleet, but no general fleet action proved possible because the principal German vessels were held at their home base at Wilhelmshaven, near the Kiel Canal, well protected by mines from assault. But on November 1st a German squadron under Admiral Von Spee decisively defeated Admiral Craddock's squadron off Coronel, Chili, the British flagship and one of the principal cruisers of the fleet being sent to the bottom with all on board. This defeat did not remain long unavenged, for on November 10th the raider Emden, after a brief but spectacular career, was destroyed, and on December 8th Von Spee's squadron was destroyed by that of Vice-Admiral Sturdee off the Falkland Islands with even greater loss, the German Admiral, his flagship and four cruisers being sunk.

On the 16th of the month a fast German squadron ventured out into the North Sea, bombarded the undefended coast towns of Scarborough, Hartlepool and Whitby, killing and wounding a large number of inhabitants, and succeeded in returning to its base unharmed. But on the 24th of the following month, the Germans on attempting a like raid, were caught by the British patrolling squadron under Vice-Admiral Beatty and beaten, so that the German home fleet has apparently never again ventured forth in these waters. Meanwhile British ships, both war and commercial, had not gone unscathed, for beside many of the latter which had been captured or destroyed, several of the former had been sunk by mines or torpedoes, while on the other hand many German war craft had been sent to the bottom.

On the 4th of February, Germany, smarting under the bottling up of her fleet, the destruction of her oversea commerce and the blocking of her imports of food and raw materials, determined upon drastic measures, and, seeking to strangle her enemy by submarine attacks on all vessels entering or leaving English ports, proclaimed the waters around Great Britain and Ireland, with the exception of a passage north of Scotland, a war zone after February

18th, and warned all neutral ships of danger if entering such zone, nominally because of the misuse of neutral flags. To this, the United States Government a week later made forcible objection, and notified Germany that she would be held to "strict accountability" should commanders of German vessels of war "destroy on the high seas an American vessel or the lives of American citizens."

On March 1st, Premier Asquith announced in the House of Commons the purpose of England and France to cut Germany off from all trade with the rest of the world, stating that: "The British and French Governments will hold themselves free to detain and take into port, ships carrying goods of enemy destination, ownership or origin," to which declaration the United States Government also made strenuous objection as being opposed to the rights of neutrals. This policy was made official by Orders in Council a fortnight later, and attempts made by the American Government, at the request of Germany, to secure mutual concessions with regard to the passage of food stuffs and war zone attacks failed.

During the month the raiders Prince Eitel, Karlsruhe and Dresden were accounted for, leaving the Kronprinz Wilhelm still afloat. But the German submarines were, however, both active and successful, while at the Dardanelles, which a powerful British and French fleet had been attempting to force since early in November, several of the attacking battleships had been sunk by mines or torpedoes with heavy casualties.

Up to this time no American life had been lost, but the sinking of the British African liner Falaba by a torpedo on March 28th, with the loss of over a hundred persons, including an American, instantly raised a serious issue with Germany, which was brought to the gravest tension by the sinking without warning of the Lusitania, with the loss of 1,154 persons, including 102 Americans, many of them women and children.

On the 13th, the President demanded a disavowal of the act of the German commander, reparation for injuries sustained and a guarantee of prevention of like attacks in the future, warning Germany that she will not expect the United States to "omit any word or act" necessary to maintain American rights. Nearly two weeks passed before reply was made, and then the sinking of the Lusitania was declared a measure of "justified self defense." A new note was dispatched on June 10th, stating that the United States must stand for the "rights of humanity," and again demanding assurances for the safeguarding of American life and property. Over six months have passed, no disavowal has been forthcoming and the material injuries remain unremedied.

While the German fleet had kept well away from the North Sea and English Channel, some of it had been engaged at various times with Russian ships in the Baltic Sea or Gulf of Riga, with varying tide of fortune, but the German submarines, while still active, were meeting new defences and attacks by the English and

a large number of them were being captured and destroyed, while their mother ships and other distant bases were being found and eliminated.

Then came the sinking of the Arabic, with a renewal of our demands for satisfaction, a long period of tension, and finally an apparent recognition by Germany of the right of the American claims so far as they might affect the future conduct of submarine warfare. But to those who are familiar with the increasing success of the plans for meeting the under-sea menace, and the psychological effect of the non-report of the fate of German submarines, with consequent demoralization of their crews, it is certain that this so-called diplomatic victory was dictated less by regard for the rights of neutrals than by recognition of the practical failure of this widely heralded warfare when compared with its declared object, the cutting off of England.

Although, according to the official British reports, 183 of her merchant ships and 175 fishing vessels, to say nothing of a large number of neutral ships, had been sunk during the first 14 months of the war, when measured by the actual tonnage afloat, this was really but a small percentage. With a reported movement of about 20,000 vessels in and out of Liverpool during the first five months of the submarine attempt at blockade, only 29 had been intercepted, and up to date the average of all kinds of craft sunk is about eight per cent, while the aggregate imports have been actually greater than during a like period preceding the war.

So successfully has the submarine attack been handled in the English Channel that all the while there has been practically free communication maintained with France without material military or naval losses. From sources of the utmost reliability, it appears that not less than three-fourths of the German submarine fleet was captured or destroyed within the first year of the war under conditions carrying special terror to the crews, and hence this phase of the present naval warfare has taken a less serious aspect in the waters about Great Britain. It has been also offset by like English activities in the Sea of Marmora and the Baltic Sea, which have materially limited the import of necessaries into Germany by way of the Scandinavian countries.

THE LESSONS OF THE WAR.

The seventeenth month of this ghastly conflict is drawing to a close, and a hundred years have lapsed since Great Britain's fleet has been engaged at sea. What are some of the lessons which he who runs may read?

A week before the opening of hostilities, Sir Edward Grey sent the following warning to the British Ambassador in Berlin:

"If as many as four Great Powers of Europe, let us say, Austria, France, Russia and Germany, were engaged in war, it seems to me that it must involve the expenditure of so vast a sum of money

and such an interference with trade that a war would be accompanied or followed by a complete collapse of European credit and industry. In these days of great individual states this would mean a state of things worse than that of 1848, and irrespective of who were the factors in the war, manv things might be completely swept away."

Beginning with an attempt to punish an insignificant nation, which for a long time ended in disaster, a continent and the outlying colonies of a continent, with fully 20,000,000 men called to arms, have vainly battled for a decisive military supremacy.

The casualties in killed, wounded and missing for Great Britain and Prussia alone, as indicated by the lists published up to the early part of this month,* are about 3,000,000, including, I assume, duplications in the lists of those who returned to service after recovery from wounds. If all the countries at war are included, the like total is probably near 10,000,000. These, be it remembered, are of those who were most fit physically; and if we take the average indicated in the British report, over 22 per cent, or the awful toll of 2,200,000 men, lay dead on the field of battle or at the bottom of the sea. And of the millions living, maimed and incapacitated for life, about 100,000 are reported totally blind.

The financial cost is so appalling as to be beyond conception. Already it is estimated that this has amounted to a total of $39,000,-000,000 for less than seventeen months' war, and that it is now running at an annual rate of $30,000,000,000 for all nations engaged, or five times as much as the total value of all the crops in the United States in the banner year of 1915, and nearly a hundred times as much as the greatest month's export in the history of this country.

What are the conditions today? With a stalemate or deadlock on land, where much the largest part of cost and casualties have occurred, and its slow process of attrition and exhaustion, the commerce of the sea, typified by the 2,000,000 tonnage of the Hamburg-American and the North German-Lloyd lines alone and a movement of nearly 80,000,000 tons of freight in and out of German ports in 1913, to say nothing of a great passenger traffic, has been wiped out of existence, and practically every port in the world debarred from German commerce except so far as it is permitted to exist by the mistress of the seas. And to that mistress the markets of all save enemy countries are open for food and munition supplies as long as she has money or credit to purchase them. That credit, as determined by exchanges in the open financial markets of the world, remains at only a nominal discount, while that of her adversaries is steadily falling when submitted to the same crucial tests.

Naval Lessons:

Such are some of the facts bearing upon life and property. What are some of the concrete lessons with regard to a naval establishment?

*December, 1915.

First, and most important, that it is a dominant power in any contest in which England or the United States may be engaged, and so long as it is kept intact and in fighting condition the nation possessing it cannot be beaten.

Second, that in the present war, despite whatever successes have been or may be won on land, the English fleet will likely prove the greatest final arbiter in settling the terms of peace.

Third, that no single type of fighting ship can be adopted to the exclusion of all others, but that a well balanced navy for both defensive and offensive purposes must possess dreadnaughts, battle cruisers, scouts, destroyers, submarines and auxiliaries, whose relative numbers and characteristics should be determined by naval experts.

Fourth, that in addition to on- and under-water craft, a numerous and powerful air fleet must be developed and a great merchant fleet is of the highest value.

Fifth, that considering the number of men withdrawn from civil life and the totals of casualties, the power per man in the naval force is enormously superior to that in a military establishment. The losses of naval officers and crews up to date are reported not to exceed a small fraction of one per cent of the total.

Sixth, that on account of the extent and accessibility of our coast line, the paucity of our mobile military establishment, the necessary defense of the Panama Canal, the upholding of the Monroe Doctrine and the protection, not alone of ourselves but of our outlying possessions, it is vital to American interests that our navy should be expanded as rapidly as possible into at least undisputed second rank, through a consistent national policy devoid of jingoism and untrammelled by conflicts of party politics or selfish sectional interests.

OUR OWN NAVAL HISTORY.

Throughout the whole period of our national existence, the United States Navy, despite its splendid record, has often been the victim of politics, incompetence, national inefficiency and official conservatism; and at critical periods has only been redeemed under conditions which can rarely be repeated by the initiative and courage of individual naval commanders, aided sometimes by manifest failings on the part of the enemy.

Let us briefly summarize the recorded facts. The birth of the navy actually preceded the Declaration of Independence, for in the fall of 1775, while military operations were being carried on against the British forces in Canada, the Colonial Congress, urged by Washington, and on the initiation of the State of Rhode Island, authorized the procuring of four armed cruisers for the protection of the United Colonies, the creation of a Marine Committee from among its own members and the raising of a couple of battalions of sailor-marines. In December of the same year the building of

thirteen frigates was authorized and a committee chosen to supervise their construction, but because of the unavoidable delay in the construction of these ships, an improvised fleet was gotten together by the purchase of a number of merchantmen, which was instructed to destroy a flotilla organized by the royal Governor of Virginia and to intercept British transports which were bringing supplies to their army and navy in this country. Failing in this, an alternative duty, the capture of a naval base in the Bahamas, was performed with a considerable measure of success.

In the latter part of 1776 occurred clashes between American and British flotillas on Lake Champlain which, although resulting finally in the defeat of the unskilled American forces, blocked the operations of Burgoyne and had far-reaching consequences. It is worthy of note that what has been claimed to be the proto-type of the modern terror of the sea, the submarine, received its first test at this early period; and more than passing mention may be made here of the ingenious and daring Connecticut Yankee, David Bushnell, who, while a student from Saybrook at Yale University, invented a submarine and, aided by the Governor and Council, constructed his "American Turtle" the year after his graduation.

Dr. Benjamin Gale, writing in November, 1775, describes this craft in great detail as follows:

"The body, when standing upright in the position in which it is navigated, has the nearest resemblance to the two upper shells of a tortoise joined together. In length it does not exceed 7½ feet from the stem to the higher part of the rudder; the height not exceeding 8 feet. The person who navigates it enters at the top. It has a brass top or cover which receives the person's head as he sits on a seat, and is fastened on the inside by screws. In this brass head is fixed eight glasses, viz., two before, two on each side, one behind, and one to look forward. In the same brass head are fixed two brass tubes to admit fresh air when requisite and a ventilator at the side to free the machine from the air rendered unfit for respiration.

"On the inside is fixed a barometer by which he can tell the depth he is under water; a compass by which he knows the course he steers. In the barometer and on the needles of the compass is fixed fox-fire, i. e., wood that gives light in the dark. His ballast consists of about 900 pounds weight of lead which he carries at the bottom and on the outside of the machine, part of which is fixed so he can let run down to the bottom, and serve as an anchor by which he can ride ad libitum. He has a sounding lead fixed at the bow by which he can take the depth of water under him, and to bring the machine into a perfect equilibrium with the water he can admit so much water as is necessary and has a forcing pump by which he can free the machine at pleasure, and can rise above water and again immerge as occasion requires.

"In the bow he has a pair of oars fixed like the two opposite

arms of a windmill, with which he can row forward, and turning then the opposite way, row the machine backward; another pair fixed upon the same model with which he can row the machine round, either to the right or left, and a third by which he can row the machine either up or down; all of which are turned by foot like a spinning wheel. The rudder by which he steers he manages by hand within board. All these shafts which pass through the machine are so curiously fixed as not to admit any water to incommode the machine. The magazine for powder is carried on the hinder part of the machine, without board, and so contrived that when he comes under the side of the ship he rubs down the side until he comes to the keel, and a hook so fixed that when it touches the keel it raises a spring which frees the magazine from the machine and fastens it to the side of the ship; at the same time it draws a pin which sets the watch-work agoing, which at a given time springs the lock and the explosion occurs.

"Three magazines are prepared; the first, the explosion takes place in twelve, the second in eight, the third in six hours after being fixed to the ship. He proposes to fix these three before the first explosion takes place."

Such was Bushnell's brilliant invention. But unfortunately, the actual success of the machine was not up to its promise or its merits. In the summer of 1776 it was taken to New York, where an unsuccessful attack was made against one of Lord Howe's ships lying in the harbor. It is likely that the attempt would have succeeded had it not been for the illness of the skilled operator, necessitating a substitute, and the fact that the latter did not find on the enemy's ship any wooden surface or copper which could be pierced, and hence was unable to attach his detachable magazine to the submerged portion of the ship's hull.

In December of this year, Benjamin Franklin arrived in France, and chiefly because of his efforts, there resulted the Treaty with France which was to mean so much in material aid and which also resulted in the intrepid career of the famous John Paul Jones, who received his first command, that of the Ranger, on the same day, June 14th, 1777, in which Congress established the Stars and Stripes as the national flag, hoisted by him in all probability for the first time on any man-of-war.

Time does not permit the details of this justly famous officer's career, but few events in naval history rank in thrilling interest with the victory of the Bonhomme Richard, a fourteen-year-old converted East Indiaman, named after Franklin, over the English Serapis. Lashed together by Jones early in the action, with his main battery soon silenced because of bursting guns but with his opponent's upper decks cleared by musketry fire, his crew was sent along the yards of the Bonhomme Richard into the tops of the Serapis, from which they showered her decks with hand grenades. With both ships on fire, his own receiving broadsides from one of

his own captains and finally in a sinking condition, Jones fought his antagonist to a surrender and then, his own ship having sunk, finally brought his crippled captive into port.

After the Declaration of Independence, and with the harbors of New York and the lower Hudson in the possession of the British as a result of the defeat of the Americans in the Battle of Long Island in 1776, Congress had taken steps for the upbuilding of the naval establishment, and at last ordered the construction of twelve ships of various types which, however, were quite beyond the capacity of the Colonies to build and equip. Meanwhile the activities of the national fleet were reinforced by ships belonging to the various states, and also aided by the granting of letters of marque against Great Britain, with the consequent fitting out of a number of privateers handled by skilled seamen. Of these latter there were, in the seven years from 1776 to 1783, nearly 1,700, carrying nearly 15,000 guns and 60,000 men. But it may be safely assumed that the days of privateering, as those of piracy, have now passed, and that no future naval war will have the assistance of such a motley throng.

Reviewing this period, the English historian Clowes states that while the British Navy had, at the beginning of the war, 270 ships manned by 18,000 men, and at the end of 1783, 468 ships and 110,000 men, they had lost no less than 202 ships, while the Continental and State Navies had lost but 39 ships and the French 72. Of merchantmen, the British had lost primarily 3,087 (including those taken by the Spanish and Dutch), and they had captured altogether only about a third as many, a total of 1,135.

The peace which came in 1783 apparently left no adequate conception of what a vital part the sea forces had played in insuring a favorable result, and as a consequence for twelve years after the close of the Revolution the Navy was practically non-existent, its last ship being actually sold in 1785, despite the fact that our merchant ship building was making creditable advance, and the advantages inherent to neutral shipping during that period of European wars had resulted in the carrying of a large part of American trade in native bottoms.

This period of naval inanition was broken in consequence of the depredations of the Barbary pirates, during which, in view of his later attitude, it is interesting to note that Thomas Jefferson, then Minister to France, on Auguts 20th, 1785, wrote:

"If we wish our Commerce to be free and uninsulted, we must let these nations see that we have an energy which at present they disbelieve. The low opinion they entertain of our powers cannot fail to involve us soon in a naval war."

And again on August 11th, 1786:

"Every rational citizen must wish to see an effective instrument of coercion, and should fear to see it on any other element than the water. A naval force can never endanger our liberties nor occasion

bloodshed; a land force would do both," which statement would hardly stand the modern test.

These outrages resulted in Congress, on the recommendation of President Washington, passing an Act in 1794 authorizing the purchase or construction of six frigates of at least 32 gun mounts (the design of some actually called for 74 guns), but providing at the same time for the cessation of all constructive work in the event of peace being declared. This happening at the conclusion of the Treaty of Peace with the Bey of Algiers in 1795, there followed an Act directing the completion of but three of the ships, the United States, Constitution and Constellation, this last, now 118 years old, still doing duty at the United States Naval Academy at Annapolis.

Realizing in a large measure the need of a more orderly scheme of naval development, Washington, in his last annual message, that of December, 1796, strongly urged the passage of laws providing for a gradual increase of the Navy, in the following words:

"To secure respect to a neutral flag requires a naval force organized and ready to vindicate it from insult or aggression. This may even prevent the necessity of going to war by discouraging belligerent powers from committing such violations of the rights of the neutral party as may, first or last, leave no other option," a declartion the truth of which was never more apparent than now.

But it was not until two years later that Congress, when John Adams was President, spurred on by the arbitrary actions of the French Government and their cruisers, was reluctantly compelled to take official action, and very grudgingly and in niggardly fashion granted the President the right to hire, purchase or build a dozen vessels, none of which, however, was to exceed 22 gun battery, and also authorized the capture of French ships. At the same time a regular Navy Department was created, separate from the Army Department of which it had been up to that time a part, and Benjamin Stoddert of Georgetown was made the first Secretary.

The splendid victories of the Constellation over the Insurgente on Feb. 8, 1799, and over the Vengeance on Feb. 1, 1800, were instrumental in leading France to desire peace, which was signed October 12th of the latter year. Credit must be given to Adams for his then attitude, as voiced in his statement to the House of Represenatives:

"I confidently believe that few persons can be found within the United States who do not admit that a navy, well organized, must constitute the natural and efficient defense of this country against all foreign hostilities."

But despite the fact that the service had acquitted itself with credit in the differences with France, Congressional ideas of economy were so pronounced that the navy would have then again relapsed into a state of desuetude had not the restless Barbary pirates resumed their activities with a declaration of war by Tripoli in 1801. During the difficulties attending this period of national danger,

Jefferson, who was then President, exhibited an extraordinary opposition to the creation of a naval force of offensive possibilities. Peace at any price seemed to be a fixed obsession with him, and referring to gun-boats as "the only water defense which can be useful to us and protect us from the ruinous folly of a navy," he advocated their construction and expressed himself as pleased "with everything which promises to improve them." His attitude was similar to those who at the present time would limit naval preparedness to a shoal of jitney submarines. In his annual message of December, 1802, he even advised the laying up of vessels so that they "should be protected from the sun," in a covered dock to be added to the Navy Yard at Washington.

In splendid contrast to Jefferson's attitude may be set the ringing words of the illustrious New York senator, Gouveneur Morris:

"When we have twenty ships-of-the-line at sea, and there is no good reason why we should not have them, we shall be respected by all Europe. * * * The expense compared with benefit is moderate, nay trifling. Whatever sums are necessary to secure the national independence must be paid. * * * If we will not pay to be defended, we must pay for being conquered."

But in spite of the pacifists it finally became evident that the continuous outrages against American ships could not go unchallenged, and war against Tripoli was practically declared in the early part of 1802. Many periods of anxiety marked the operation of the navy in the three years before this was brought to an end in 1805, during the settlement of which Captain Rodgers uttered his famous dictum that "Peace on honorable terms is always preferable to a war," the converse of which, "A righteous war is preferable to a dishonorable peace," is equally axiomatic.

Naturally, at the end of this war the spirit of the navy was in consequence of its successes highly satisfactory, and the way was plain for an intelligent expansion of it. But the false spirit of economy still prevailed, and on the recommendation of President Jefferson, despite the advice of Gallatin, his Secretary of the Treasury, who urged the use of a surplus estimated of at least two million a year, which he rightly considered would be lost in case of war, wholly "to the building of ships of the line," the opposition in Congress again brought the navy to a low ebb, to correct which even the national dangers due to the threatened complications with England, France and Spain were not sufficient incentive. This was a period of indefiniteness as to the rights of neutrals, and hence was marked by many arrogant activities against American ships which were sought for contraband and British subjects, a result which is invariably the accompaniment of national weakness. Even when the Chesapeake, having refused to surrender some of her men, was, on June 22nd, 1807, fired into by the British frigate Leopard and struck her flag, the national indignation culminated for the time being only in a refusal to permit British ships to enter American water,

this incident being followed by the Embargo Act, by which American vessels were not only forbidden to leave our ports but all foreign ships were forbidden to bring cargoes into them. American commerce was, in consequence, threatened with total ruin, but after being in force a little over a year this Act was modified in February, 1809, and limited in its force to trade with England and France.

Referring to this initial period of unpreparedness, I may quote the following from Chadwick's "Relations of the United States and Spain":

"Whether with or without a war, a Navy would have saved us the six years of humiliation which were to intervene between 1806 and 1812; it would have saved the embargo which was to tie to the wharfs in rotting idleness more than a million tons of shipping which had been engaged in foreign trade; to bring grass-grown streets to our greatest ports, and strain the sentiment of the several sections of the Union to the point of separation. It would have saved the war of 1812, the capture and burning of Washington, and the shameful ineptitude, with one brilliant exception, of our army commanders in that contest. * * * There would have been no such Orders in Council as those directed to the destruction of American commerce; or had these come before America was ready with her navy there would have been quick renunciation."

We were, however, without that adequate navy and England's acts at sea kept intensifying our differences with her. Finally, when, notwithstanding the fact that France had repealed her orders, she refused in spite of her promise to modify her course with regard to neutral crews, Congress, in response to a message from President Madison, on the 18th of June, 1812, declared war against Great Britain on account of the: "Impressment of American seamen, the extension of the right of search to United States war vessels, the 'paper blockades' established by the British Orders in Council, and the alleged attempt of Great Britain to persuade the northwestern Indians to attack the Americans."

But although during the period preceding this declaration, Congress had, under the able leadership of Clay and Calhoun, been led to augment the military and naval forces, the declaration of war, which was actually followed by the recall of the Orders in Council five days later, found the United States at such a grave disadvantage in the matter of armed forces that even although Great Britain was still at war with Napoleon, the outlook was most serious. Confronted with a conflict against a country of over double its population, skilled in the art of war and undoubtedly mistress of the seas, the United States possessed no ships-of-the-line, her largest floating unit was a frigate, and her most numerous class the useless gun-boats which had been built under Jefferson for coast defense.

The disparity of numbers of available ships stamped this declaration of war as an example of sheer audacity, for our total

naval force, excluding the practically useless gun-boats, comprised an even dozen of ships of various classes, while Great Britain's naval forces from which she could draw ran into the hundreds. It was inevitable that superiority of numbers would eventually drive the American Navy from the seas, but to the undying glory of the service, many victories were achieved of the utmost importance and resultant influence on account of their demonstrations of courage and seamanship, notably those of the Constitution over the Guerrière, the Wasp over the Frolic, the United States over the Macedonian, and the Constitution over the Java, all in 1813. And, of course, the privateers which had been authorized were successful in capturing many British vessels and thus inflicting serious losses.

The effect of these captures in England bordered something upon consternation, and, as quoted in McMaster's "History of the United States," were well voiced by the London *"Pilot"* in the following:

"Five hundred merchantmen taken and three frigates! Can this be true? Will the English people read this unmoved? Any man who foretold such disasters this day last year would have been treated as a madman or a traitor. He would have been told that ere seven months had gone the American flag would have been swept from the ocean, the American navy destroyed and the maritime arsenals of the United States reduced to ashes. Yet not one of the American frigates has struck. They leave their ports when they choose and return when it suits their convenience. They cross the Atlantic, they visit the West Indies, they come to the chops of the Channel, they parade along the coast of South America. Nothing chases them; nothing intercepts them—nay, nothing engages them but to yield in triumph."

During the following year the successes at first lay with the British, the Chesapeake and the Argus being captured, but in September the fortunes of war again changed. The British ship Boxer was captured, and then came Perry's victory at the Battle of Lake Erie, which was followed by the Macdonough's defeat of the British flotilla on Lake Champlain. But meanwhile the British fleet had ascended the Chesapeake, Washington had been occupied and burned, Boston, New London and New York were blockaded, and naval expeditions were undertaken against Mobile and New Orleans, the latter to be coupled with one of the most disastrous defeats suffered on land by the British.

But Great Britain, which had long before revoked her Orders in Council, had long desired peace, which was signed on Christmas Eve, 1814, and for an even century she was destined to patrol the seas before she was to engage in another ocean conflict.

The feeling of satisfaction in England was not, however, unalloyed, and found expression in the London *Times* in its issue of December 30, 1814, when it said: "We have retired from the combat with the stripes still bleeding on our backs. Even yet, how-

ever, if we could but close the war with some great naval triumph, the reputation of our maritime greatness might be partially restored. But to say that it has not hitherto suffered in the estimation of all Europe, and, what is worse, of America herself, is to belie common sense and universal experience. Two or three of our ships have struck to a force vastly inferior! No; not two or three, but many on the ocean and whole squadrons on the lakes; and the numbers are to be viewed with relation to the comparative magnitude of the two navies. Scarcely is there an American ship-of-war which has not to boast a victory over the British flag, scarcely one British ship in thirty or forty that has beaten an American. With the bravest seamen and the most powerful navy in the world, we retire from the contest when the balance of defeat is so heavily against us." This plaint of the Thunderer might have been somewhat assuaged if it had taken to heart the fact that the blow had come from English descendants and not from her continental antagonists.

Had the war lasted much longer it might have been that the toll would have been even a more bitter one, for during this war an American civilian, Robert Fulton, planned a unique sea-going battery which was completed four months after his death and made a successful trial trip on July 4, 1815. This ship, the "Demalogos," afterwards called the "Fulton," may be said to have been the first American armored vessel built, for she had sides five feet thick, sufficient to resist any solid shot then used, and carried a battery of the heaviest guns afloat. Of 156 feet length, 56 feet beam and 20 feet depth, she had a tonnage of nearly 2,500, greater than that of a line-of-battle ship. She had no sails but was propelled by steam, her motive power being carried nearly below the water line. A single paddle wheel, carried amidships, was operated in a channel beyond the reach of shot. Had this remarkable craft been completed earlier and had been fortunate enough to have engaged an enemy's squadron, it is probable, barring accidents, that she would have sunk or dispersed it and perhaps then and there changed the entire course of naval development. But in the absence of actual proof, it was looked upon simply as a novel experiment too revolutionary to meet with naval approval. She was, therefore, relegated to the duties of a receiving ship and was blown up by her own magazine in the Brooklyn Navy Yard in 1829.

The conclusion of peace with Great Britain soon found us again in arms against the Algerians, and here Decatur won renown for the navy by a final victory within a month and a half after leaving his home port. The conclusion of the Peace of Algiers and Tunis put a final end to the Barbary trouble. The spirit of the navy was now at its best, and Congress itself was awakening to our new responsibilities as a world power. It had been impressed by the possibilities of the "Fulton" and the construction of another similar battery was authorized in 1816, but this was opposed by the ultra-conservatism of the men at the head of naval affairs, who were so

wedded to the idea of sail-power that they would not give serious thought to the possibilities of steam-propelled ships. During the nearly score of years which intervened between the authorization of this second sea battery and the taking of measures to carry out the mandate of Congress, a dozen sail-driven ships of the line were built, some of which were utilized as late as the Mexican war.

In 1835, the then Secretary of the Navy, recognizing the growing importance of steam propulsion and the necessity of the recognition of its vital bearing upon naval operations, directed the construction of our first steam-propelled man-of-war, which was completed two years later and attained the respectable speed of twelve knots. Her propelling power was a pair of side paddles driven by engines on the upper deck. The contract for the ship was followed by that of several others of like type, one of which, the "Michigan," completed at Erie in 1844, was built of iron and for many years did service on Lake Erie. Meanwhile the civilian engineer again came to the front, when R. L. Stevens, the son of a Col. Stevens who had in 1812 prepared plans for an armored steam vessel, made an offer to the Navy Department to build an iron-clad steamer of high speed in which the works, including the propelling machinery, should all be below the water line. Although begun thirteen years later, it was never completed, but another revolutionary construction, again by a civilian, had taken concrete form, that of the iron-hulled screw-propelled 1,000-ton steamer "Princeton," built in 1842-3 by the Swedish engineer, Capt. John Ericson, who, having failed to interest the British Admirality in his invention, had, with the effective aid of American Consul Ogden at Liverpool and on the advice of Capt. Stockton of the United States Navy, been induced to come to this country in 1841. Not only was this ship the first naval vessel of any nationality to be provided with screw propulsion, but it was also the first to have forced-draft boilers and engines all well below the water line ordinarily protected from gun fire. In passing, it is well to recall that many of the inventions of this illustrious engineer were designed for naval use, such as means for checking gun recoil, for measuring distances at sea and for taking ocean soundings.

It is to the credit of Congress that within four years its Navy Committee, after duly considering the advantages of the new departure in ship construction, recommended the building of thirteen ships of this character, and equally striking is the evidence of conservatism under the influence of those educated in the older school that when in the following year authority for the actual construction of four ships was granted, a Board composed of naval officers of high rank recommended that paddle wheels should be used on three out of the four and also that one of them was built of wood. But the day of doubt and pessimism as to the new motive power was passing, and Congress four years later advised the building of six

first-class frigates to be provided with screw propulsion. These ships were of the justly famous Merrimac, Minnesota and Wabash class, but enough of prejudice still remained to subordinate steam to sail power, as evidenced by the full rigged spars and the small auxiliary engine power, a mistake which was partially remedied in the ships of the Hartford class authorized in 1857, in which, while the full sail rig was retained, the engine power was increased.

The years intervening before the Mexican war of 1846 were chiefly spent by the navy in routine work, punitive expeditions and exploration, and in that war itself there was little opportunity for naval activity. From its close in 1848 to the next national crisis was but thirteen years, a period of rapidly multiplying changes in ship and gun construction. But for a decade the insistent mutterings of the coming storm had gone unheeded, and military and naval needs were left neglected by Congress. It is typical of that shortsightedness so often characteristic of democracies, even when rushing headlong into danger, that in the last days of the session which closed in June, 1860, the estimates for repairs and equipment for the navy were, at the instance of Senator Sherman of Ohio, cut down a million of dollars, and Senator Pugh of that same state said: "I think we have spent enough money on the navy, certainly for the service it has rendered, and for one I shall vote against building a single ship under any pretense at all."

And then the politician Lovejoy: "I am tired of appropriating money for the army and the navy when they are of no use whatever. * * * I want to strike a blow at this whole navy expenditure and let the navy go out of existence. * * * Let us blow the whole thing up! Let these vessels rot, and when we want vessels to fight we can get mercantile vessels and arm them with our citizens."

Well may Senator Tillman, Chairman of the present Senate Naval Committee, denounce as traitors to their country the past and present politicians of the Lovejoy class. One can almost hear the Tavenners, Baileys and Bryans of our present pork-day and pacificist generation. At the time of these blatant attacks, and within a few months of the opening of hostilities, the whole existing steam navy of the United States consisted of but twenty-three vessels which could be reckoned upon as serviceable, and about half as many of little value for any purpose. Had the National Government possessed an adequate fleet and a reasonable standing army, and the early command of such forces been in adequate hands, the Civil War with all its horrors might have been avoided. When the war began the duty of the naval force was instantly apparent—to blockade the Southern ports and to occupy the Mississippi—but some idea of the bigness of the task may be gathered from the fact that in nearly 3,600 miles of coastline from Virginia to Mexico, there were nearly 200 usable harbor and river openings.

In April, 1861, the Merrimac and eight sailing vessels were

burned and scuttled at Norfolk, the former to be raised by the Confederates and converted into a powerful ironclad. Then followed the creation of a national fleet by construction and purchase, which, beginning with less than a dozen ships immediately available, was augmented by nearly six hundred by the end of 1864, while from the South the Albemarle and Shenandoah, English built and manned, and hundreds of blockade runners were crowded into service. Again in a national crisis the civilian engineer came to the front, not only in this great area of upbuilding, but especially in the person of Ericson, whose "cheese-box on a raft," the combination of his own and the genius of Timby, who invented the revolving turret, appeared in Hampton Roads on that memorable 9th of March, 1862, the day after the rail-clad Merrimac had sent the gallant Congress and Cumberland to the bottom, saved the rest of the Northern fleet from destruction and changed the course of naval construction. The Monitor type, in its old form, has, it is true, largely passed away, but the low free-board and the revolving turret remain the essentials of the modern battleship, typified in the great superdreadnaught, the Queen Elizabeth.

With the details of naval construction and operation during the Civil war, we need not at the moment be concerned, but attention may be called to the building in 1864 of another submarine, the "Intelligent Whale," by a later Bushnell and associates, which failed on its trial in 1872 and now adorns the Brooklyn Navy Yard; also the sinking of the monitor Tecumseh by a mine and the daring destruction of the ironclad Albemarle by a spar torpedo on the night of October 27th, 1864. But in general the navy had done its work well, and besides lending effective assistance to the army, had finally established a blockade of most rigorous character. Before the end of the war, every Southern port was effectually closed and the Confederacy brought to the extreme of poverty in all, save courage, necessary to continue the war.

The surrender of Lee at Appomatox on April 9th, 1865, brought peace, but with it, during the disorderly period of reconstruction, a stupid lack of comprehension of the vital, if not spectacular, part the navy had played in bringing the war to a successful conclusion; and while the rest of the world was taking heed of its lessons the navy was slowly drifting backwards in shameful neglect. By 1880 the navy, with its antiquated wooden ships and equally useless ordnance, had sunk to such a low ebb that it was the laughing stock of the world, for it was even less effective than the fleets of some of the South American republics. But in 1880 the then Secretary of the Navy appointed a board to consider the needs of the service, who reported in favor of a building program for 68 ships of various types, to which recommendations Congress, in magnanimous fashion, responded by authorizing in August, 1882, the building of two small ships and a year later two more. At the same time, the number of officers graduating from Annapolis was reduced in such drastic

fashion that for ten years not only was promotion blocked and deficiencies in detail emphasized, but the whole spirit of the corps was brought nearly to demoralization.

I am still young enough to glance back to the days closely following this period. Graduating from the Naval Academy in 1878, where my practice cruises were made on the famous old Constellation, I made my first foreign cruise on the Richmond, which sailed from New York in the winter of 1878-9, bound for the Asiatic squadron as the flagship and to act also as the escort of General Grant on his visit to the far East. She was not a very formidable craft, but typical of the best ships in the service at that time. A wooden hulled vessel of 2,700 tons, she carried a battery of 14 smooth bore guns mounted on wooden carriages. She was full rigged to royal masts, and also provided with engines of less than 2,000 horse power driving a single screw which could be uncoupled whenever sail power was being used. She was lighted with candles and oil lamps, guided by the needle compass and steered by hand. Part of the time under sail and part under steam, she was thirty days going from New York to Gibraltar and nearly six months elapsed before we reached our destination at Yokahama.

After a short tour of duty on similar ships, the Minnesota and the Lancaster, on the former of which I had, in 1881, vainly tried to introduce the electric light, I was fortunate enough to get orders to the Crystal Palace Exhibition at Sydenham, England; and I may be permitted to refer to the fact that in the spring of 1883, about the period of my transition from a naval to civilian career, I made a report to the Navy Department urging the use of electricity, from which I quote the following:

"I would replace this costly troublesome and ineffective system by one of much higher efficiency and of probably no greater cost, one whose advantages can scarcely be realized save by actual experience. I would replace every light in the ship save the deck lanterns, some bunker lights and a few others in out-of-the-way places. I would have not only the same lights as are used at present, but a number of others, which the new method would enable me to use advantageously. And such a system, I hold, can be placed in a ship which will be of the most reliable character and give every possible satisfaction.

"The presence of a dynamo on board ship has other advantages besides those of ordinary lighting. Among the several uses to which it could be applied are the following:

"Search Light.—For the present the arc light will continue to be used for this purpose on account of its intense specific brilliancy and the necessity of great power. When so used the carbons should be placed out of line so as to get full effect of the crater in one direction. The light can be placed wherever desired on deck with its requisite reflector, or on a covered deck and reflected up a tube, as has already been done. Such a light can be used to search the

water for torpedo boats, for boats away from the ship in a gale, for deserted ships, for shoal water and breakers, for inspecting an enemy's operations on shore, for lighting up a ship in case of night work or collision, or for throwing an enemy's ship or fortification in full relief.

"Signaling.—The incandescent lamp itself for signal purposes at night, using either white or colored lights worked by a properly intermitted current, the light being placed on a yard-arm or mast-head.

"Diving.—The work of diving could be much facilitated by sending down an incandescent lamp of, say, 30 or 50 or more candle power. Often the propeller, rudderpost, or valves could be inspected from the surface by immersing a light on the end of a rod in proximity to the part to be inspected. This would sometimes prevent great delay and would shorten the actual operations of a diver when working in cloudy or muddy water.

"Torpedoes.—The dynamo and general circuit could take the place of the ordinary hand dynamo or battery, and with much more certainty of operation. Connections could be made either temporarily or permanently.

"Battery.—Since a horsepower can be developed for 30 pounds dead weight, by an adaptation of the general circuit the whole broadside battery of a cruising ship could be most effectively worked through the medium of electricity. The guns could be run out or in by means of a pump and its hydraulic compressor, and trained with a rapidity and facility, an absence of confusion and noise, and a freedom from the moral effect that the slaughter of a gun's crew entails such as can never be obtained with modern broadside guns if worked with a large and unnecessary number of men. I propose at a future date to elaborate such a system. The firing of and signaling to and from guns can be easily accomplished by the new method.

"Steering.—As steam has now become common in all of the best merchant vessels and men-of-war, so electricity in time can and will be called upon to fulfill the same functions and with the same certainty and delicacy of operation.

"Illumination.—An occasional use of incandescent lights, white and colored, will be for the purpose of ship illumination on the occasion of national fetes, temporary circuits being run."

All of which sounds rather strange today in view of the present universal use of electricity on board ships.

It was not until 1885, during the first administration of Cleveland, that the turn for the better came in the navy, beginning with the authorization by Congress in 1886 of the construction of the small battleships, Maine and Texas, followed four years later by the Indiana, Massachusetts and Oregon. But it was years before the steel manufacturers of the country, private establishments cooperating with the navy department, were able to respond to the

demands of naval construction, just as it was years before they were ready to meet the needs of industrial electrical developments.

In 1895 came the famous Venezuelan message of Grover Cleveland and the happily passed crisis with Great Britain, but three years later, at the beginning of the war with Spain, after the blowing up of the Maine in the harbor of Havana, we had in service only four battleships of the first class, one of the second, two armored cruisers, eleven protected and twenty unprotected cruisers, besides six monitor type vessels, eight torpedo boats and a dynamite gun-boat, a total of fifty-three ships of every class. It is fortunate that they were not pitted against a first-class naval establishment, for otherwise even the skill and readiness which characterized the destruction of the Spanish fleet by Dewey at Manila in a two-hour action on May 1st, 1898, and that of Cervera's squadron at Santiago by Admiral Sampson's fleet on July 3rd, which with a few minor actions compasses the naval actions of this war, might not have been so effective.

Such is the brief history of a navy whose personnel, even under adverse circumstances and neglect, during the hundred and forty years of its existence has upheld the finest naval traditions and reflected honor upon the American name. Since the close of the Spanish war, much, indeed, has been done for the development of its fighting units, reflecting the greatest credit on our naval organization, but considering the possibilities emphasized by the conduct and extent of the present war, we are in many things vital to a proper condition of preparedness, whether in numbers and balance of ships, adequateness of crews, equipment and munitions, or provision for air and under-water auxiliaries, woefully deficient. And if we would avoid the possibilities of national disaster, the country must be aroused from its complacent lethargy and be prepared, both on land or sea, to face the responsibilities of a world power, whatever may be the necessary cost to the national treasury and whatever our individual personal burdens and sacrifices, for if the individual citizen is to claim national protection and share in the benefits of national prosperity so must he equally share in preparation for and participation in national defense. And in so far as that defense is naval we may well ponder and take to heart the words of Rear Admiral Chadwick:

"As one attempts to look into the future the vastness of the possible changes startles the imagination, but in it all is ever present the power that goes with the ubiquitous warship, from whose threat no port of the world is free. Military power fades to insignificance, through its narrow limits of mobility, when compared with the meaning of a great fleet."

THE CIVILIAN ENGINEER.

What then can we, other than in the ways which we are already naturally active, do professionally to aid in the upbuilding of a fleet which will fitly represent the country?

I have already pointed out how vital changes in ship construction and armament were gradually being introduced into the navy service through outside activities prior to the Civil War. But no one can compare even the best creations of that date with the magnificent specimens of the fighting machine composing a modern fleet without realizing to what degree the work of the civilian engineer has made possible these great engines of destruction. And by engineer I mean the modern industrial creator, whether he be known as inventor, engineer, manufacturer, for without their joint work the battleship of today would be an impossibility. That is not a reflection upon officers or organization, for the trained experience, knowledge of the fitness of things and the skill of naval design are equally vital to success. But this is the day of scientific attainment—of steel and armor plate, turbine and oil engines and electric drive, of electric light, storage battery and motor, of telephones and wireless communications, of the gyroscope, compass and repeater, of smokeless powder and high explosives, of mines, torpedoes and submarines, of aerial bombs and flying craft, into the development of every one of which the names of the civilian inventor and engineer have been indissolubly woven within our own times.

In the old days the commanding officer of a ship was essentially a sailor, trained to handle his sail-driven ship under every condition of weather and to fight in any emergency. Other than his complicated assemblage of spars, rigging and sails, in whose handling he was a past master, his ship was a simple structure and little changed in its essentials in a century. His battery was equally simple, man-handled and absolutely dependent upon the efficiency of its gun-captains. Skill, self-reliance, alertness, endurance and courage, all these were the attributes of the naval commander, and none better have trod the quarter deck of any man-of-war than those whose names are found in the records of our navy.

The same personal qualities must and do characterize the officer of today, but the full rigged ship with all its romance is gone and the dreadnaught is but one of many kinds of fighting craft. The routine duties and knowledge required of the commanding officer have been increased, and he is now an executive in command not only of a ship but of a corps of experts on whom its operation depends. Without vital sacrifice of what is essential he cannot be a jack-of-all-trades, for if so he will be master of none; nor can his subordinates be expected to be highly trained physicists, chemists, designers or constructors. Their province is to operate, and to maintain in a condition of perfect readiness for operation, the multitude of intricate mechanisms entrusted to their care.

Outside the service the time long since came when it was necessary to specialize, and if we are to get the most effective results in the navy it will be necessary to utilize every man along those lines for which he is best fitted and in which he can be most efficient, as

well as to secure the fullest co-operation with the knowledge and skill incident to our national industrial development.

THE NAVAL CONSULTING BOARD.

One laudable attempt to aid in this object was the creation of the Naval Consulting Board by the Secretary of the Navy. Its inception lay in an interview of the New York Times with Mr. Edison, in consequence of which on July 7th last Secretary Daniels wrote to him asking if he would, as a service to his country, act as the chairman of a Board of Inventions, through which the navy might be able to avail itself of the inventive genius of the country in order to meet the new conditions of warfare. At first only a small Board was contemplated, to be concerned simply with the question of inventions and experimental work. Feeling that the matter was of the utmost importance, and that the Board should be expanded and the selection of members determined on broad lines, I took the liberty of suggesting to the Secretary that experimental equipment should take into account the needs of both services, because researches could be carried out jointly more effectively and economically, that on account of the confidential character of the work the members should be of American birth, and that besides inventors there should be included engineers who deal with constructive problems and the practicability and value of inventions in the same manner as they now do for great commercial organizations.

It seemed vital to guard against the presence of any one on the Board, no matter how eminent, whose early training had been in countries in which not only military and naval training was compulsory but where it was taught and the Government claimed that there was a life duty to the state superior to the specific obligations presumably assumed when applying for citizenship in an alien country. I further urged that the presidents of the national and some other engineering societies should be called into preliminary consultation, assuring him of their hearty co-operation and that they could be relied upon to submit suitable names for consideration as members. Serious consideration of these suggestions was promised, and the general proposal meeting with the concurrence of Mr. Edison, a few days later the Secretary announced his intention to leave the selection of members to a named group of national engineering societies, the presidents of each of which were requested to determine by letter-ballot, or in some other representative manner, the names of two members to serve on the Advisory Board.

The original personnel of the Board and the societies electing them are, as officially announced:

Member-at-large and Chairman: Thomas A. Edison, the Dean of American inventors.

American Chemical Society: Dr. W. R. Whitney, director of Research Laboratory, General Electric Company; Dr. L. H. Baeke-

land, expert in photo chemistry, electro-chemistry and organic chemistry.

American Institute of Electric Engineers: Frank J. Sprague, inventor and pioneer of the modern electric railway, and consulting engineer; Benjamin G. Lamme, inventor and chief engineer, Westinghouse Electric & Manufacturing Company.

American Mathematical Society: Dr. Robert S. Woodward, president, Carnegie Institute of Washington; Arthur G. Webster, Professor of Physics, Clark University, Worcester, Mass.

American Society Civil Engineers: Andrew M. Hunt, consulting engineer; Alfred Craven, chief engineer, New York Public Service Commission.

American Society of Mechanical Engineers: William LeRoy Emmet, inventor, and mechanical and electrical engineer, General Electric Company; Spencer Miller, engineer and inventor of rope drives and cable systems.

American Institute of Mining Engineers: William L. Saunders, inventor of machinery operated by compressed air, including drilling and quarrying devices; Benjamin B. Thayer, mining expert, and president of the Anaconda Mining Company.

Inventors Guild: Dr. Peter Cooper Hewitt, inventor of the mercury electric lamp and rectifiers; Thomas Robins, inventor, and president of Robins Conveying Belt Company.

American Electro-Chemical Society: Professor Joseph W. Richards, expert metallurgist and mineralogist; Lawrence Addicks, metallurgist and electrical engineer.

American Society of Aeronautic Engineers: Henry A. Wise Wood, inventor of printing machinery and aeronautical expert; Elmer A. Sperry, inventor of electrical and mining machinery, and of the gyroscope compasses and stabilizers.

American Aeronautical Society: Matthew B. Sellers, aeronautical expert and technical editor of "Aeronautics"; Hudson Maxim, inventor of ordnance and high explosives.

American Society of Automobile Engineers: Howard E. Coffin, gas engine expert and vice-president of Hudson Motor Company; Andrew L. Riker, mechanical engineer and vice-president of the Locomobile Company of America.

Later Dr. M. R. Hutchison was added by Secretary Daniels and Mr. Henry Wise Wood resigned for personal reasons.

Four members are graduates of the U. S. Naval Academy, and nine are members of the American Institute of Electrical Engineers, an accidental tribute to the widespread activities of that profession. Personally, I think some other societies might have been added with advantage, as for example, the National Academy of Sciences, the American Physical Society and the Society of Naval Architects and Marine Engineers. The list, however, is fairly typical of the American inventor and engineer, and it has the advantage of not being a sensational one; rather, it may be termed a working board because each man on it is active in the work of his profession.

February, 1916

When Secretary Daniels decided upon the method of selection adopted, and steadily resisted personal and political pressure to make appointments at large, he took a unique and in fact the most advanced step of its kind yet taken by a public official, the result of which, if the members of the Board justify their selection, promises to be far-reaching in its consequences, for the engineering profession will at last have been recognized by a democratic government in a spirit of confidence in their patriotism and ability. Not only has a new departure been made looking to up-building and making more effective a most important department, but there has been rendered the engineering profession and those who here represent it a signal honor. I am sure that I rightly express the spirit of every member of the Board and those whom we represent when I say that in so far as lies in his power each will help make this departure in government practice a success which will redound to the credit of all concerned.

But before our first meeting many queries and conclusions were but natural. What, for example, was our fitness for this particular task? We come from various walks and many absorbing interests in professional life. While a few have had some naval training, all are essentially civilians, knowing little of the profession of arms and especially of the navy. Manned by officers educated by the Government at great expense, the service is representative to the last degree of the best democracy of this country, and we, instead of being qualified to teach them something of their profession could only hope to bring them some aid from those great fields of engineering endeavor with which we were affiliated. And in order to be of service to them, to pass with a reasonable measure of intelligence on matters pertaining to their business, a somewhat intimate acquaintance with, and knowledge of officers and crew, ships and their equipment was essential. It was also necessary that the officers of the navy should fully understand that what we first sought was a sympathetic understanding with their real needs.

The Board, of course, has no authority whatever in law; it is not in the employ of the Government and no executive function can be delegated to it. We must recognize that those whom the government has taught are thoroughly capable of command, they have learned the elements of their profession in an unsurpassed institution, the Naval Academy at Annapolis, and experience afloat has widened their conceptions and their capacity. Fighting if need be, and at all times preparation for fighting, is their trade. They are familiar with its tools and they are skilled in their use, so they must be the ultimate judges of what is useful and material. The unhappy war which is devastating Europe will determine the value of many a weapon of defense or offense on land or sea; and one immediate problem in preparedness will be a selection from those things and practices which have already been tried out. But other things will be shown—the failure of many hopes and prophecies, the causes of

failures, new methods of defense and offense, and to those who are ingenious enough the way for marked advances. In some fashion, then, the members of this Board, be they sufficiently alert and have the aid of the active minds both in and out of the service, may prove useful.

Every war proves an occasion for a renaissance of Keelyism, and thousands of inventions, so named by their progenitors, are born with stalwart and inarticulate cries. The majority of them die aborning, a few reach the teething age, still fewer that of youth, while only here and there one survives to maturity. But now and then some die because of lack of nourishment, not because an early tombstone was their fittest ornament, for the motive power back of most inventions, however meritorious, if they are brought to the fullness of success, is the hope of financial return—not alone to the inventor but to those who provide the sinews of war to carry the invention to success.

The ordinary training of a naval officer tends to make him analytical, and in the regular course of his duties his time is well occupied in preserving and making use of what has been entrusted to his hands. Unless special opportunity is afforded for active development out of the usual routine, by the time he rises to bureau administration he may become unduly conservative, and, with loss of virile powers, find it difficult to adopt new methods, or to approve any departure from previous practice in which there may be some element of risk. Yet within the service there are many men of exceptional inventive and engineering capacity who, if given but fair opportunity, can produce inventions of the highest importance. Many such there are now to their credit despite the inherent difficulties, but at present there is lacking much of the incentive essential for creative work.

At various yards, notably at Brooklyn, there are sundry laboratories and facilities for making tests, but these are only of moderate size and fairly equipped, besides being fully occupied with a great variety of tests and reports of standard character with regard to the materials used in the service. Every government machine shop, too, is crowded with regular work, and unavailable for any general experimental development. It seemed, therefore, that the Government should recognize what the great electrical and other manufacturing corporations have already realized, that one of the most effective instruments with which it can equip itself is a thoroughly up-to-date research laboratory and machine shops, backed by ample appropriations, to insure that inventions of promise, whether made by officers in the service or by men outside who would seek government aid, may be promptly and profitably developed.

The determination of the originality and value of inventions is one of the most important and thankless of tasks. No matter what one's technical equipment and experience may be, we all know from sad experience how difficult, often impossible, it is to pass upon the

merits of untried inventions, how prone one is to error when expressing judgment upon the work of others, whether from a lack of understanding or because of failures of our own which may have resulted in a prejudicial bias. Then, too, our own experiences have demonstrated the futility of most inventions, and the long and thorny road over which one must travel even when success is the final goal. Many men, whether from personal suspicion, lack of trust in others or from self-confidence and special knowledge, are reluctant to submit their inventions to others who may be interested in like developments. With this attitude we can all sympathize, for few men care to entrust matters of great importance and possible value to the critical judgment of other men having no personal interest in them; and with regard to some inventions and under certain circumstances it would be folly to do so.

It was with the foregoing ideas mentally formulated that I attended the first meeting of the Board on October 8th at the office of the Secretary of the Navy at Washington, at which every member, including Mr. Edison, was present. The program outlined called for informal gatherings on that day, in order that the members of the Board, many of whom were strangers to each other, might get together, and also in like fashion meet the secretary and the various heads of bureaus before organizing for work. This program worked perfectly, for after a heart to heart talk in the secretary's office, at which he outlined his general purpose, and an adjournment to the White House to meet the President, the Board embarked upon the "Mayflower" for a trip down the Chesapeake to the Indian Head Proving Grounds. An excellent opportunity was thus afforded to get together in various groups and discuss the purposes and possibilities of the Board. At the proving grounds the members were put in immediate touch with the practical tests of ordnance, large and small, as represented by the 14-inch 50-calibre naval gun and the Colt rapid fire automatic, as well as with the manufacture of gun cotton and smokeless powder. At the evening session the various heads of the department who form the regular Naval Advisory Board detailed some of the problems with which their department was concerned.

The next morning's session was devoted to organization, which was quickly and smoothly effected, and plans laid for conduct of the business of the Board. There was an election of officers, Mr. Edison, of course being the chairman, with Messrs. Hewitt and Saunders vice-chairmen, and Mr. Robins secretary. Then followed the adoption of rules of procedure, and subject to the criticism of the department, the classification of committees, this last being essential in view of the great diversity of subjects on which opinions might be required. The name of the Board, in view of its possible duties, was changed from the "Naval Inventions Board" to the "Naval Consulting Board of the United States." The afternoon was largely taken up with consideration of a Naval Research Lab-

oratory and Experimental Station, the recommendation for which had already been determined on and which was preceded by an exposition of the research facilities now available in the department. The matter being primarily referred to a special committee, with certain concrete suggestions advanced by Mr. Edison, the project was considered somewhat from the standpoint of individual occupations, but when the matter was taken up by the full Board the larger aspect of the case prevailed, with the result that it recommended the establishment of a general laboratory which, when fully developed, would cost in the neighborhood of five million dollars for land, buildings and equipment, and, when fully in operation, might require an annual expenditure of about two and one-half million dollars, this amount including about half as much now specifically provided in the annual appropriations but which can be diverted on the authority of the Secretary as may seem best.

Some criticism has been directed against this proposed laboratory, possibly because of undue brevity in the public announcement with regard to it, but sometimes at least by people who neither know nor apparently care what the actual project calls for. Invention cannot be commanded, says one, it is a divine afflatus which descends only on chosen shoulders; but most of us believe with regard to inventions as Edison is quoted as having said regarding genius, that it is one per cent inspiration and ninety-nine per cent perspiration. "Necssity is the mother of invention," and a somewhat careless mother at that, as is evidenced by the various conflicting claims of paternity when the child is sufficiently promising. Successful invention is usually simply the engineering solution of problems which arise in the course of industrial development, or become apparent because of individual inquisitiveness. The world is full of inventors—it has few geniuses, and the business of this Board is not to provide the latter but to help utilize the former. I might add that it is not proposed that the members of the Board as such have anything to do with the operation of the laboratory, nor that it shall encroach upon the prerogatives or interfere with the usefulness of any existing facilities for research, such as for example the Bureau of Standards. But perhaps no one better than electrical engineers understand with what lavish expenditure experiments must sometimes be made; and it is certain that responsible naval officers keenly appreciate how vital the element of time may sometimes prove, and how important it is to have the novel projects which are incorporated into new naval designs thoroughly tested, so far as they can be, beforehand, instead of submitting a great battleship to the risk of failure at some critical time.

At the first of the meetings subsequent to the one at Washington the membership of the committees, following mainly individually expressed preferences, was determined and each committee elected its own chairman. Some idea of the character of questions which

may arise is indicated by the sixteen subject heads settled upon after discussion with officers of the department, as follows:

Chemistry and physics; aeronautics; internal combustion motors; electricity; mines and torpedoes; submarines; ordnance and explosives; wireless and communication; transportation; production, organization, manufacture and standardization; ship construction; steam engineering and ship propulsion; life saving appliances; aids to navigation; foods and sanitation; and public works, yards and docks.

The ordinary procedure adopted with regard to specific inquiries or new inventions is for an officer detailed by the navy department to first sift out such as do not need to be referred to the Board. On those which come to it all members are expected to express an opinion if they have any, after which the subject is referred to the proper committee, with a final report back through the Board to the Department. Individual members are not, of course, expected to be active in making inventions save as they would naturally be concerned if not connected with the Board, except as greater familiarity with the navy might lead to some special activity.

The work of the Board is not even now confined to consideration of specific problems which may be put up to it by the navy department, but may often be the result of discussions among its members, as instanced by the following example. One would ordinarily assume that with a reasonably powerful navy, well equipped and manned, an army of reasonable size similarly equipped and factories capable of turning out a goodly supply of arms and ammunition, we would be well armed for an effective defense. But on what does the success of all of these primarily depend? Ammunition, which in turn is dependent upon an ample supply of nitrates. At present our munition manufacturers, public and private, rely upon the crude form imported from Chile in the form of saltpeter, and so far as I know this country has no natural supplies. Without ample storage, then, of the natural product or means for making nitrates synthetically, should we suddenly be deprived of the incoming supply our army and navy after the exhaustion of their regular ammunition and supplies would be helpless. It requires no great stretch of imagination to realize that in time of war one of the first and most easily achieved objects would be the prevention of the importation of saltpeter into this country, either by attacking the ships carrying it or interference with the supply at its source.

It follows, then, in any adequate scheme of preparedness, that the Government should provide against the contingency of failure of supply of the basis of ammunition manufactured. This can be done in either of three ways: Storage of enough for the demands of a war lasting possibly three years, the annual cost being the interest on a capital cost of say twelve million dollars, plus any depreciation; or the erection of plants suitably located inland as to

power and other supplies, where the manufacture of nitrates can be carried on even at some loss; or by a combination of the two methods, the maintenance of storage sufficient for, say, a year's use, and the establishment of a unit plant or plants for the fixation of nitrogen, where a thorough technical force could be organized, and which could within a year of the opening of hostilities be duplicated while new technical forces could be trained until expert.

We, therefore, took steps to recommend this latter plan to the Navy Department. It is a happy augury of the activity being manifested on the subject of preparedness that within a week of our action, Major General Crozier, the head of the Ordnance Department of the Army, in his annual report just issued, makes the same recommendation with regard to the supply of nitrates because of his own independent investigation.

Another direction in which commendable activity is being shown is the work undertaken by the Committee on Production, Organization, Manufacture and Standardization, which is not only engaged in steps looking to the standardization of the manufacture of aeroplane motors, with whatever interchangeability of dimensions of different makes as is possible, but is also planning to educate Government aviators by establishing a course of training in the motor assembling and testing departments of the great automobile factories; and to supplement this training with theoretical instruction by weekly lectures given by the men whose life work has brought the gas engine to its present efficiency. Another project initiated by this same committee is a widespread district determination of the manufacturing resources of the country, so that there may be reliable information of the possibilities of munition manufacture in case of emergency.

It may not be amiss here to suggest that the possibility has been indicated of supplementing the present highly efficient air-driven torpedo, by an alternative type, a purely electric one, although a personal inspection of the best of its type, the Bliss-Leavitt, under the guidance of Mr. Leavitt himself, has impressed me with the magnitude of the problem. When it is realized that the present torpedo is the result of fifteen years of strenuous development over the original Whitehead, and that the total weight of battery and motor to replace the compressed air-flask and motor, and which must reliably develop say 120 horse power for ten minutes, must be less than a thousand pounds total weight, electrical engineers have an indication of the limitations imposed and the difficulties to be overcome.

While the purpose of the Board as created is as has been stated, if its present activities should be confined simply to a consideration of specific inquiries by the department, or the merits of such inventions as may after having been properly sifted out be referred to it, or which may perchance originate among its members or their associated interests, I think that its usefulness will be unnecessarily

restricted. Whatever scheme of naval policy may be planned by the administration, and whatever the recommendations by the navy department, all of which must of course be largely initiated and passed upon within the latter, Congress, which through its naval committees must approve all proposals, is the final arbiter, for it only can authorize the necessary expenditures and it must justify itself before the country of which it is the popular representative.

That body is composed of many men of many minds, representative of widely diversified beliefs and interests. They may generally be divided into three classes—those who believe in and will support any reasonable measure of naval and military preparedness, those who are always opposed to such for various reasons, and finally those who are "from Missouri" and have to be shown. We must assume that all are actuated by sincere beliefs, however at variance their conclusions, and that all are inherently patriotic and have the country's interests at heart. They represent, however, the civilian side of our national life, and one fact must be recognized. However sound the recommendation which may emanate from a body of naval officers under our present system, no matter to what rigid scrutiny they may be subjected by a civilian secretary, and no matter how critically reviewed by the Senate and House Naval Committees, there is, after all, a feeling on the part of many that the recommendations are necessarily tinged with professionalism, as against the normal pacific policy and intentions of the country.

But there has now been called into being a non-political engineering board, selected by civilian scientific societies, serving not only without compensation but meeting all their own expenses, and so far as possible removed from the taint of self-interest in any augmentation of naval or military establishments. They constitute no man's board and are no man's rubber stamp. They form, in fact, a connecting link between the professional fighter and the civilian who pays the bills, and as such ought to be in a position to express without undue prejudice their convictions on many matters incident to naval preparedness, up to the limit of their knowledge and capacity. Such expression might easily be influential when approval of a bill is hanging on even balance.

It would, therefore, seem wise that the continuity of this Board, which by reason of its very existence must be in confidential relation with the navy department to such limits as it may determine, should be officially authorized by Congress. If then put in touch with the administration's plans, suggestions or criticisms might be invited before final decisions by the department. Then to the extent that such plans command understanding and approval the members of the Board could be prepared to support the same, and advocate a broad, consistent and rational scheme of preparedness based solely on the needs of the whole country, uninfluenced by politics or sectional prejudice, and destined to maintain at all times an adequate and thoroughly efficient naval defense.

Eventually I hope to see naval estimates prepared, under the direction of the Secretary of the Navy, by a regularly constituted general staff of continuing character, backed by a civilian technical board and a national council of defense, as well as the adoption of a budget system of expense instead of the present detail system. While I am not unmindful of the many difficulties in the way of bringing about this revolution in present methods, I cannot but believe that ultimately the demands for the efficient and economical administration of public business must accord with what has been found essential in the conduct of great private enterprises—a reasonable latitude in expenditure of monies under expert guidance, untrammeled by unnecessary arbitrary restrictions as to details.

Every man, whether he is connected officially with the Board at this time or not, should do all in his power to advance the state of mind of the public toward the realization of the necessity for preparedness. Like the rest of you I am sometimes pretty busy in my own affairs, but the other day when I urged upon the Board at its last meeting the necessity of every man getting as far as possible intimately acquainted with the details of the naval service, and said he ought to sacrifice, if necessary, some of his own time and pleasure and some of his business interests to get some experience on board ships when trial speeds were being made, when submarines were being tested both afloat and submerged, and when target practice at sea was being indulged in, an old classmate of mine in command of the New York, one of the best modern ships, turned to me and said: "Sprague, I'll take you at your word. We are going to sail next week for Cuba for fleet exercises and target practice at sea. Do you want to go along?" That was a pretty general proposition, for I did not know after we left New York Harbor when we would get back, not from lack of confidence in the naval service, but simply when we got to sea with no orders to get back to New York within two or three months, I thought maybe he would have me marooned somewhere. I said, "Where are you going? What accommodations have you? He said, "We have got an admiral's cabin. Is that good enough for you?" I said, "Yes, that will do." He said, "Come along with your books and baggage. I won't entertain you. Make the ship your home; go where you please; criticise us, what you will, you are welcome. We will take you out to sea, give you fleet manoeuvres and target practice, for a month or six weeks. If you think you cannot stay the longer time, stay the shorter. We may intercept some ship at sea if necessary and send you back to New York. Will you come?"

It just happened to catch me at a time when my business affairs could not very well be neglected, but I consulted my associates and

I thought it was my duty to go. They said, "Go ahead, and stay as long as you please."

So next week I am going out to learn something of the old profession from which I retired many years ago, and when I get back I hope I am going to be able to tell my associates on the Board that it is up to them to do the same—go out and do something, learn what we are talking about, have a little personal pride in the service we have back of us.

Out here in Chicago you are a thousand miles away from the sea shore. That means probably 975 miles farther away than some shell on the Atlantic coast can reach you; but it does not mean you should not have an interest, because if any adequate foreign force should ever land on our shores, there is no telling where they will get unless we are prepared for them.

DISCUSSION.

W. E. Williams, M. W. S. E.: I would like to ask, if it is no secret, what sort of defense has been the most efficient against the submarines, developed by what is going on abroad?

Mr. Sprague: Of course the English government is doing its best to suppress information about submarines. A good deal of information does come through, sometimes from the captains of ships and also through our naval attaches, as well as through naval officers abroad and those associated with them.

It has been the policy of the English government not to publish how many submarines have been sunk, for this reason; they count upon the psychological effect upon the mind of a crew who go out on very arduous service having instilled into them a very grave doubt whether they will ever come back, or what kind of fate may await them.

Now there have been probably not less than sixty to sixty-five German submarines captured or sunk. The English navy was not prepared at first for these attacks. If it had been there would not have been so many English ships sunk in the early part of this war; but after—I am not speaking now as a member of the Naval Advisory Board, but only as an individual—after the sinking of the Lusitania and the Hesperian, and after the crew of a submarine which had been captured threw a bomb at the destroyer which had taken it at sea, a feeling, I think, grew up in the English naval service, very much I think as grew up among the English forces in Flanders when some Englishmen found some of their men crucified. No quarter was granted until there was a change of the attitude of attack.

Now it is reported, and I guess it is probably true, that many portions of the English Channel are protected by steel nets of very large mesh, about twelve feet, in sections which can be detached very easily and are floated by buoys which can be seen very easily.

The submarine is blind when under water, and now with two or three thousand English patrol boats, trawlers and one thing and another searching the seas, it is rare that a submarine dares to put its periscope above the water in daylight. They come to the surface at night to recharge their batteries, and even then their presence is indicated by the throbbing of their Diesel engines which are used for surface propulsion as well as for charging the storage batteries, which latter are of course in more or less constant use especially when under water.

Consider a ship in a fog and how absolutely helpless it is; the submarine under water is in the equivalent of a permanent fog. As it goes along it suddenly becomes entangled in one of these meshes. It does not know it at first. Pretty soon it begins to drag, to pull back. By and by it catches the propellers. It has fouled the vanes on the sides. A submarine is held in the water in two ways. When it is awash the water is out of the tanks, and when they want to submerge water is taken in and she goes ahead with the side vanes at a slight depressing angle. She is kept almost in a state of water buoyancy. In that state she is in a state of almost unstable equilibrium unless she is actually in motion, and in a heavy sea she will roll at a fearful rate. As she plunges her head in this net the net begins to close around her. By and by she is entangled and her propeller is fouled. She must come to the surface in order to clear it. She is just as apt as not to be sighted and fired upon by any one of a number of patrol boats; or they may see her and simply follow her, always following the bobbing heads of the net buoys. Rumor has it that in view of the attacks which were made by the submarines and the feeling that this is illegal warfare—that is, attacks upon unarmed ships and without notice—a large number of those submarines do not come to the surface for several days. When they do come to the surface there is nothing to do but take the bodies out and put in some more men. Of course it is a horrible death, slow dying in vitiated atmosphere.

No doubt there are other ways. Some are caught by patrol boats, fired upon and sunk, and some have been sunk by ramming. In fact, I think the boat which did such great damage at first was rammed by a battle ship after a vain attempt to torpedo it.

Then there have been attempts to sight submarines from aeroplanes. Aeroplanes being much faster, if they once sight a submarine they can follow it. They signal patrol boats, the patrol boats follow, and after a while the submarine must come to the surface and it is then subject to attack in a good many ways.

There is no doubt in my mind that the so-called diplomatic victory which was supposed to have been won was won because the submarine warfare had got to that stage.

As far as the English navy is concerned, not one-fourth of one per cent of its force had been lost. It is reported that more naval ships have been laid down and put overboard since August, 1914,

than the total tonnage of the United States Navy. The type of battleship cruiser—I think we have none in this country—illustrated by the Tiger, the Lion and others of that class, develop about 125,000 horse power in their engines, and have a speed of about 31 knots an hour. Superdreadnaughts of the Queen Elizabeth class develop about twenty-five knots an hour.

Of course the English Admiralty has been very chary about announcing any losses when they did not have to. You remember the Audacious was lost by a mine or torpedo submarine on the north coast of Ireland. She went down in a very short time. Most of her crew was saved; I think all of them. We heard of the Audacious being repaired, floated again and out again. It is now said that it was a new Audacious. Of course it is perfectly permissible in a nation not to supply its enemies with unnecessary accounts of its own troubles and losses. That is, I think, practiced among all nations.

There have been attempts to locate submarines by sound under water. They can hardly be located by the sound of the propellers, but they are all driven by motors which are geared up to pretty high speed, and that peculiar whine of the motor which we often hear over a telephone is very clearly discernable. By microphonic receivers stationed at different places they get so that by locating the direction from which they get the largest volume of sound the location of the submarine may be determined. Notice is then wirelessed to patrol boats who start over a plotted square with the idea that in time that submarine has got to come to the surface.

All this, of course, does not mean that the submarine has not a great future and is not a fearful instrument of destruction, because it is.

Plans for a destroyer for the French government have been made by an American concern to be worked by turbine engines.

Our own service have submarines of 1,000 to 1,400 tons underway, some which we hope will have a maximum speed on the surface of twenty-four knots an hour and fifteen or sixteen under water; they will be very useful pieces of apparatus in defense.

Of course for a battleship her greatest defense is her own speed if she knows where danger is, because she goes much faster than the submarine under water. If the submarine comes above water she can defeat it. Another defense is the torpedo boat destroyer, which can make from twenty-three to thirty-five knots an hour speed. You have perhaps no definite idea of the range of a torpedo, and the time it takes to travel to its object. The biggest torpedo we have in this country today weighs about 2,800 pounds. It has a range of 10,000 yards, and next year will have a range of about 12,000 yards, far ahead of that of any foreign torpedo that I know of.

I spent some two or three hours recently with Mr. Leavitt, who is the principal designer and engineer responsible for the outgrowth

of the American torpedo, and he told me about the painstaking care and difficulties in constructing torpedoes, remarking that had he known fifteen years ago the detailed labor that he had to go through to bring the torpedo into its present state of efficiency, he would not have undertaken the work for all the money there is in the world. He said, "Any man that can build a torpedo now and improve upon it is welcome to do it, I won't do it."

These torpedoes, governed by a gyroscope, can be projected laterally at right angles from a side of the ship. The gyroscope is set so that when she goes overboard and plunges into the water, although she wiggles around in an erratic way for a few moments, she will soon straighten out and run on the course required. She starts out with a speed of perhaps thirty or thirty-five knots an hour, but if she is making a long range attempt, say six miles, corresponding to 10,000 yards, it takes about ten minutes to get to her destination, so that the chance of hitting a ship at long range is very small.

You know a torpedo is never steered with a mid-ship rudder. It is always steered with a hard over rudder, because if you attempted with a rudder that is only an inch in length and perhaps five or six inches in depth, to steer a torpedo in one straight direction with a mid-ship rudder you would have an error in that steering which would invariably appear, and she would go wide of her mark. So the torpedo is always steered with a hard over rudder and it shifts, under control of the gyro, from one side to another very rapidly. Consequently the path of a torpedo is a slightly varying path around a mean, and in that way they can get accurate work. In long range, four or five miles, if you have no waves, no current and the ship is not moving, she can be struck by a torpedo; but if the ship is moving and there are tides, eddies and current, it makes it difficult to come up to the perfection aimed at in our service.

If I were in charge of the United States government no torpedo would ever go out of the country. I would provide for taking over a definite and large output.

You know they are spoken of as air driven torpedoes. That is something of a misnomer. Air is simply one of the means of getting motive power. Air is started with pressure of 2,200 pounds in the main flask. And, by the way, there is nobody in the world except our American manufacturers who apparently now make flasks equal to those now demanded in the American torpedo.

The 2,200 pound air is brought down to 450 pounds, and that is the pressure at which the engines work. Every pound of simple air at that pressure has, I think, somewhere about 25,000 foot pounds of energy, but there is actually in the torpedo about 140,000 pounds of energy per pound of air, and that is got by simply heating a water spray and the air by alcohol jets, so that they are using heated compressed air with steam mixed with it.

Albert Scheible, M. W. S. E.: I would ask if any headway has been made along the wireless control of torpedoes?

Mr. Sprague: Yes. Young Mr. Hammond has made considerable progress, I think, in that direction. But personally I do not feel strongly impressed with the utility of a wireless directed torpedo. The present torpedo is absolutely deadly at any reasonable range, and is also very high power. Now if you want to control a thing some miles off, how are you going to do it? Ships open fire today at, say 18,000 yards, over ten miles. At such a distance the effect of a shot can hardly be seen by the ship that fires it, but may be reported to it, as is reported was done in one of the actions in the North Sea, by destroyers intermediate between the attacking and the attacked ship. How is one going to see even five or six miles away accurately enough to control the direction of a torpedo? I think the conditions of fighting will rather prohibit that clarity of atmosphere or the use of directing masts of the character which will be at all useful at long distances. And, furthermore, if you can direct a torpedo of that character by wireless from shore, what in the world is to prevent a ship being attacked having a counter-attack on that wireless communication? You may say that we will have a selective wireless wave, but then it is perfectly possible to have wireless apparatus on the ship which will go through an enormous range of wireless waves; and it seems to me that such a torpedo would in a short time be put in a position where it would execute the most erratic movements that could be imagined, something like an ordinary torpedo would if the gyroscope got out of order.

Mr. Williams: The British Admiralty were reported as saying that they might armor the bottom against torpedoes by raising the draft, two inch or four inch armor.

Mr. Sprague: It is very hard to get the facts.

Perhaps one of the most interesting things that have been developed is the Sperry gyroscopic master compass and repeater. It is now used on all the French and English submarines. I may note that recently English submarines have managed to get through the narrow openings of the Baltic Sea, which is heavily mined, and have attacked ships carrying freight from Scandanavian countries to Germany, with a great deal of effect. The captain of one of those crafts only a short time ago said his success in getting through the extraordinary narrow, tortuous channels was due in a large measure to the use of the gyro-compass, because the ordinary compass was entirely too erratic and unreliable in that particular region. He was pretty far north. That is an illustration of what electrical engineers have been able to furnish.

I think very likely that Mr. Sperry's work will result in the effective stabilizing of our submarines.

When you get down in one of them your first impression is that you are in a laboratory of a machine shop of most complicated character. The front end is stopped off by four or six torpedo tubes. Towards the rear end are the oil engines, and abaft them, driven from the same shaft, but in a separate compartment, are the

air compressors necessary to drive the water out of the torpedo tube after the torpedo has been fired under water and also for ejecting water out of the ballast tank. Then there is the apparatus for operating under the rudder and elevating planes. Of course you have not the most excellent facilities for cooking, because the ordinary fumes of cooking are at least unpleasant. Along the sides every inch of space is taken up by switches and indicators of every kind and character. In fact, I am familiar with modern switchboard rooms, but I think the submarine can discount them all in the necessary awkwardness in which things have to be arranged. A submarine has to be built of the same metacentric height for fore and aft and lateral displacement. In other words, a very little bit of displacement waste would make her very erratic, and the rolling capacity of a submarine—well, those who have to ride in a submarine say it amounts to several thousands of degrees in a very short time.

It is necessarily pretty hard on the men, and especially when out for any length of time. The present German submarines operating in the North Sea have not the aid of a mother ship from which they can get their supplies. Leaving their home port they take some days to get to their destination, cruising around there perhaps a week or ten days, and take an equal time going back. Away perhaps for about three weeks, they have to lay off for a time to recuperate and another crew is taken on. When these submarines are expected back in three weeks and they do not come in for several weeks, the next crowd that go out wonder what has become of them. By and by stories get current of this or that submarine being caught in a net and never being heard of again. No report is made —it never gets back to Germany. The submarine may be recovered and towed in, but no word is sent. Those men are lost and that is the end of it. That has been the most demoralizing force which the German navy has had to meet. There is no reflection upon the German officer or sailor, because courage is a common attribute of all humanity. Men will go out and face death, but men like to have at least a chance, and they would rather fight in the open air.

Stafford Montgomery: I would like to suggest that Mr. Sprague give one or two other examples, in addition to the production of nitrate and the electrical driving of the submarine, examples of the work of this Board. I also want to ask if the Board intends to pursue the old policy of secrecy in regard to all its activities, or whether it will follow the modern commercial policy of getting all the publicity possible and co-operating with the general engineering public.

Mr. Sprague: The Board is not an official board. If it were one it would probably be governed by what it was told officially to do. It is now a board created by courtesy. At present its members are not authorized to discuss a great many matters that come up before it. Some things, of course, can be discussed openly, like this ques-

tion of nitrates, with a possibility of interesting the country and determining the creation of plants for the fixation of nitrogen. All those are matters which men on that Board are not only willing but are glad to discuss where they think it is not a sacrifice of certain confidential matters, and they hope to receive the aid of members of engineering societies.

You will understand that the members of the Board are not there because of their own importance or because of any particular conceit on their part. They are simply there as representatives of various engineering societies. I am in hopes, as matters develop, that these societies will have committees who will co-operate as associate members. I shall not hesitate to go to any associate in the electrical profession, and say, "Can you give us any suggestions to help in the Navy Department?" because, after all, it seems to me it is the least he can do.

Now, I mentioned the possibility of supplementing the present air-driven torpedo. Of course the present torpedo has to be built with an extraordinarily heavy steel flask, if you have 2,200 pounds pressure. It has been calculated that if that boat could be driven electrically an eighteen-inch torpedo might have of its present weight probably 950 pounds available for the new power.

Now the question is: Can we for that 950 pounds, build any kind of a battery, storage or primary, specially constructed of course, and any kind of a motor, which will permit of a power development of 100 to 120 horsepower, say for eight or nine minutes' run, so as to drive a torpedo, say at forty knots an hour speed; and at the same time ever live to do the same thing a second time? This thought leads to the consideration of a new possibility and a very hopeful one, the building of a motor which depends for its short time of operation upon the absorption of heat in the metal parts rather than upon radiation, in perhaps five or six times the ratio, to come to a temperature not any greater than is found in thousands of motors run, be driven at a speed of perhaps 3,500 to 4,000 revolutions, and geared down to the double shafts necessary to drive the torpedo, which may develop for the short time necessary 100 to 120 horsepower with not over 300 pounds weight in the motor. That is going some, if it can be done, and I am rather inclined to think, although a month ago I would have laughed at the proposition, that it is going to be possible. That will leave about 650 pounds for the battery. Now the expert chemists have the task before them to see whether they can build a battery which will stand up and turn out the necessary energy for eight to ten minutes. I believe it is possible, but it is not a simple proposition any more than the building of the present torpedo is a simple one.

A torpedo is one of the most erratic things on earth, and one of the most sensitive things. After you get a torpedo running fairly well you may alter the design and weight of some small part, then

throw the torpedo overboard, and she will develop erratic tendencies.

Note an illustration of the refinement with which torpedo apparatus has to be built: The gyro of the torpedo is perhaps four inches in diameter. Of course it is polished like glass. It runs on ball bearings, and is gotten up to a speed of 15,000 revolutions in four-fifths of a second. Why does it have to be that quick? A man gets all ready to fire a torpedo and he does not necessarily point his boat or his torpedo at the ship. He simply points his gyro at it. His ship is in motion, and perhaps swerving, and the other ship is in motion, but he has got to follow that just as a man follows a gun. He cannot change the gyro after it is in motion, but having sighted the object at which he is going to fire that torpedo the gyro must be suddenly brought to the enormous speed of 15,000 revolutions in the shortest possible time. This is done by a small turbine which is geared to the gyro and after a certain number of revolutions unlocks itself automatically. It all happens, as I say, in a very short time. Now, you can eject the torpedo as you please within a range of ninety degrees, and she will straighten herself up, and that gyro will be the power which initially operates the mechanism which controls the rudders. The gyro moves certain parts which permit the engine of the torpedo to open and close valves which operate the rudders, and these rudders go first one side and then the other, many times a minute.

Mr. Williams: Is it possible to construct a steel net that would resist a torpedo fifteen or twenty feet away from a vessel?

Mr. Sprague: A great many torpedo nets have been built, but a torpedo weighing 2,800 pounds with cutters of the character which can be made today, and running perhaps 25 knots an hour, would go through almost any net which it is practicable for a ship under way to carry. A ship lying at anchor in port could carry a pretty heavy net, and probably would not be attacked except at short range. If attacked at such range, a torpedo might be followed with two or three others, one after another. The first one would blow the net to pieces for a pretty big space and the second go right through the net. But a torpedo can cut through almost any net a ship under way might carry. A ship is terribly impeded by any size of net.

A member: Why cannot submarines be fitted with peep holes so that the nets can be seen?

Mr. Sprague: There have been a good many projects for using electric lights under water. Possibly some good will come of it, but water is pretty dense to light, that is, to see anything in detail, and especially to see anything as small as perhaps a quarter or three-eighths inch wire, particularly wires twelve or thirteen feet apart. In any case it is apparent that it cannot be seen quickly enough to stop with sufficient certainty. Even if a boat is going fourteen or fifteen knots an hour it does not take long to go the distance beyond which it would be able to see anything like that. In fact, sub-

marines have been very close to each other, almost close enough for collision and had only a comparatively short time to avoid it. You remember the first contest between two submarines, an Austrian and an Italian. They came very close to each other in the Adriatic. Neither of them had the slightest idea the other was there. One of them came up and was awash. The other one came up and the commander happened to have his eye at the periscope and saw the Italian about a hundred feet away from him. He happened to be so pointed that he could let go his torpedoes and the Italian was sunk. You cannot always do that. It takes time, you have got to locate your submarine. It is not like a destroyer. A destroyer has torpedo cradles on deck and they simply launch a torpedo out of the side, but a submarine has its torpedoes in its eye at the bow. You have got to swing the whole submarine so as to point at the object before you can do anything with the torpedo.

A member: What explosive is used in the torpedo, and how is it ignited?

Mr. Sprague: Gun cotton or its equivalent. It is ignited by percussion. Here is a curious thing which perhaps some gentleman can explain. I cannot. There is practically no appreciable difference in the speed of a sharp nosed torpedo and a torpedo with a natural semi-spherical head. The end of the war head has different kinds of mechanism to operate the fuse. They have preventive means so that the thing cannot operate at all except after a certain run, because otherwise she might go off in contact with one's own ship. But they are intended, whether they strike end or not, to operate with the percussion fuse.

Torpedoes are arranged for variable depth of operation. The German torpedoes at one time were set at a fixed depth of twelve feet. The English, who are using some shallow draft Monitor type ships off the coast of Belgium, have been fired at a great many times, but the torpedo always went too low. The normal depth was about ten or twelve feet because that is sufficiently low not to be disturbed by a choppy sea and sufficiently high to secure destruction of any ordinary ship.

H. H. Evans, M. W. S. E.: I think we all owe a great deal to Mr. Sprague for his instructive paper to us. I am very glad the questions brought out all the details of engineering which run throughout the ship from one end to the other. In fact, the modern ship is nothing but engineering from stem to stern. Most of us are more or less familiar with the dramatic changes which have come about in naval warfare—transitions from wind to steam, and from wooden ships to iron ships, from unarmored ships to armored ships, and slow firing guns to fast firing guns; but I think we people in the interior are not apt so much to realize the enormous number of engineering details which demand attention from people inside of the service and outside of the service, and there, I think, is a very

great field for those of us who wish to help in national defense to devote our engineering ability.

We can take it in either one of three directions.

We can of course take an intelligent interest in the service, appreciate the problems of the service, appreciate the needs of the service. As we get into it, we appreciate we need aeroplanes, we need repair shops, we need a great many auxiliaries which are not provided for nowadays. The tendency in the mind of the average Congressman seems to be if they provide battleships they are through. They do not realize the battleships break down, and they break down in foreign waters, so you have to have a fully equipped machine shop to accompany them to keep your fleet in condition to fight. It is of no use to you if it is not. As we take an interest in it we are able, of course, to interest the public, so that public opinion will be aroused to the point where the Congressman will have the prodding and the backing that will make them generousely provide all these needed auxiliaries.

And I think if we get into it we will realize there are a great many things within our own particular specialty, whatever particular line of work we are working in, which the man inside of the service does not know about. Special steel that is developed, special electrical equipment that is developed, special devices of various kinds, which we have worked out maybe for a coal mine, or worked out for a smelter, or something of that kind, which fit very nicely in naval service.

Then I think it is more or less up to us as good citizens to familiarize ourselves with the service in a general way, with the ships, with the equipment, with the auxiliaries, with the apparatus that is used on board ship, for the reason that the ships of the navy now are notoriously under-manned and under-officered. We have not enough men to send all the ships we have to sea at the present time. We certainly are not going to have enough to send auxiliaries to sea. We have fighting ships now which we cannot keep in commission. They have to be kept in the navy yard with a skeleton crew. We have not enough men on shore now for inspection duty and things of that kind. When war comes, all the men who are now inspecting steel, who are looking after equipment in various parts of the country, who are on shore stations or at navy yards, have got to be moved up into the fleet. We have got to take these ships in the navy yards, fully man them, fully officer them, and put them in the fighting line. That is going to take all these men in the interior of the country. Somebody has got to move into this place. He has got to be an engineer. You have got to have a man with a machine shop record to go into those yards. You must have a man with rather a broad knowledge of steel to go down there and take that inspection duty. You have got to have things go out in a hurry. There is a question whether a slight departure from a specification is going to be suitable or whether it is not. As an army officer said

the other day, the mere fact of having an inferior grade in the leather in leggings sometimes meant that an army corps went to pieces on the march and sometimes it did not.

War is a fearful strain on men and service ships are uncomfortable at best, but in war times you have got to be ready to fight at any time. You have your hatches battened down, you have your air ports closed. You have very uncomfortable, unhealthy conditions. On top of that you have an enormous nervous strain.

I happen to have been down on the Santiago blockade myself. We had a fairly comfortable ship, but because of the fact that we were expecting the Spanish ships at almost every moment we had to keep all air ports closed and we had to rely on artificial ventilation. It was a bad thing to start on any kind of work in an atmosphere of that kind. On top of that the more responsible officers had a continuous strain. In war time a submarine may pop up under you at any time and the ship is sunk. Men are going to break down under that strain; they are going to have nervous prostration; they are going to have to be sent home. We have not enough men as it is.

So I think it is up to us civilian engineers to at least get a general knowledge of the Navy, get a general knowledge of the problems so that we shall not be absolutely green when we move up into the second line, so that these fellows who are now on this non-military duty can go out and take their places in the fleet.

202a

age 203, first paragraph, third line, "5th" should read "12th."

IN MEMORIAM

HERBERT MERRILL WHEELER, M. W. S. E.

Died November 12, 1915.

From its list of living members to the roster of the honored dead. Such is the transfer of the name of Herbert Merrill Wheeler, who died on the 5th day of November, 1915.

Mr. Wheeler was a native of Shawano, Wisconsin, where he was born February 26th, 1876. At the age of twenty he graduated from the University of Minnesota, receiving the degree of Bachelor in Electrical Engineering June 4th, 1896. From 1896 to 1898 he was a student at the Fort Wayne Electric Corporation, Fort Wayne, Indiana. During the years 1899 to 1903 he was electrical engineer for the Chicago Union Traction Company.

Mr. Wheeler then turned to teaching at the Lewis Institute, Chicago, Illinois, and from 1903 to 1907 was Instructor in Mathematics and Engineering. In 1907, when the City Council of Chicago passed the ordinances for Rehabilitation of the Street Railways, Mr. Wheeler became Electrical Engineer in charge of installation of conduit and cables, which position he held till 1909, when he was made Assistant Chief Engineer of the Chicago Railways Company.

In 1904 he became Junior Member of the Western Society of Engineers, in 1906 an Associate Member and in 1909 a Member. He became chairman of the Electrical Section and member of Board of Direction in January, 1915.

We who knew Mr. Wheeler prized his friendship and appreciated the force of character and intelligence back of his quiet manner, and we feel that the profession has lost a useful member.

He was loved and respected as a teacher and honored as an able loyal and faithful engineer. On the Board of Direction he was tireless in his efforts to advance the profession of engineering.

Memoir prepared by P. B. Woodworth, H. B. Fleming and P. Junkersfeld, Committee.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

REVIEWED BY JOHN F. HAYFORD.*

GEODETIC SURVEYING. By Edward R. Cary, M. Am. Soc. C. E., Professor of Railroad Engineering and Geodosy, Rensselaer Polytechnic Institute, New York. John Wilsy & Sons. Cloth: 5¼x3 in.; pp. ix + 272; 98 illustrations. $2.50 net.

The methods of geodetic surveying have been changing rapidly in the past fifteen years. Hence there is much difficulty in keeping a text book on that subject up to date, as this book certainly is. The author has drawn largely and with good judgment upon publications by the United States Coast and Geodetic Survey both for text and for illustrations.

The topics, Reconnaissance; Base Lines; Triangulation; Computation of Triangulation; Trigonometric Leveling, and Precise Leveling, are covered clearly and adequately. Probably on account of a severe limit of length which the author had set for himself, his treatment of the topics, Map Projections; Time, Longitude, Latitude, and Azimuth; and the Method of Least Squares, is so severely condensed as to be much less satisfactory than the remainder of the book.

A convenient, short, suggestive list of books on geodetic surveying, astronomy, and least squares is given at the end.

Especially to be commended for their freshness are the parts of the book dealing with precise leveling and the measurement of primary base lines. On each of these topics the reviewer knows of no text book so fully up to date as this one.

It has not generally been appreciated how fully the accuracy of a triangulation depends upon the shape and character of the figures of which the triangulation scheme is made up. Even among experts there has been a general and fundamental misconception of what constitutes a strong figure in triangulation. This book gives the standard table now available for determining the strength of a given figure and such information as would enable a thorough man to use the table. It is to be regretted in this case, as in various others in the book, that the corresponding theory is not developed far enough to enable one to understand it.

It is clearly an error of judgment to give the zenith telescope method of determining latitude but a part of one paragraph in this book in which the method of determining time with equally large and rare instruments is allotted fifteen pages.

The chapter on Method of Least Squares is so severely condensed as to make it of moderate value only, a common mistake in connection with this topic. The applications of this method as given throughout the book are excellent.

The book contains some errors of judgment, such as are inevitable in dealing with so difficult a subject.

The positive virtues of the book so far outweigh the minor defects of the character which have been indicated above that both the teacher and the surveyor in the field applying geodetic methods will find the book satisfying as a short, well-written, well-arranged, up to date text.

THE STRUCTURE AND PROPERTIES OF MATERIALS OF CONSTRUCTION. By G. B. Upton. John Wiley & Sons, New York. 6 in. by 9 in., 325 pages. 1916. Price $2.50.

The author states that this book is the outgrowth of the laboratory course in Materials of Construction given to Juniors in Sibley College at Cornell

*Director, College of Engineering, Northwestern University, formerly in charge of Geodetic Surveys in the Coast and Geodetic Survey.

University. He explains that it is restricted almost entirely to theoretical discussion and is divided into two parts, the first part dealing with the determination of the properties of the materials by means of engineering testing and the second part dealing with the nature of the internal structure of materials and the control of properties through the control of the internal structure. In the author's words, "this part of the book becomes a short study of theoretical and applied metallography." Certain parts of the book the author claims as new or in greater detail than heretofore given. Among these are the general analysis for the finding of true stresses after the yield point in torsion and transverse loading and the detailed description and explanation of heat treatment from the standpoint of physical chemistry.

Following is the table of contents:

Chapter—

Pole and Tower Lines for Electric Power Transmission. By R. D. Coombs. McGraw-Hill Book Co., New York. 1916. 6 in. by 9 in., 272 pages. Price $2.50.

This book is written from a structural standpoint, the author stating in the preface that "The number, size and voltage of wires and the type of insulation to be used belong to the field of electrical engineering, while the subsequent determination of the best method of carrying the conductors across country is purely a question of civil engineering," using the terms "electrical" and "civil" in their narrow sense.

Notwithstanding the fact that the computation of stresses, and the determination of sections for such structures as steel towers, is covered in variuos text-books, there are numerous general conditions, the author states, in which transmission-line work does not follow the accepted standards and methods of other structural design. He compares the various column formulas, for instance, with special reference to steel towers for transmission lines and throughout the book goes into detail both as to theory and practice.

The book is well written, is fully illustrated and has a good index. The contents are as follows:

Chapters—

I—Types of Construction.
II—Loading.
III—Wires and Cables.
IV—Design.
V—Wooden Poles.
VI—Steel Poles and Towers.
VII—Special Structures.
VIII—Concrete Poles.
IX—Foundations.
X—Protective Coverings.
XI—Line Material.
XII—Erection and Costs.
XIII—Protection.
XIV—Specifications.
Index.

Water Purification Plants and Their Operations. By Milton F. Stein. John Wiley & Sons, New York. 1915. 6 in. by 9 in. 258 pages. Price $2.50.

The purpose of this book, as stated by the author, is to give instructions for the operation of water-purification plants as simply and concisely as is consistent with reasonable completeness. The subject is treated with special regard to the non-technical operator of small plants, but certain portions have been treated more elaborately because, as the author says, "experience seems to show that graduate chemists have some difficulty in grasping certain phases of the work on assuming charge of a purification plant." Numerous examples are given of various types of plants with detailed description of the component parts. The book has about 90 illustrations in addition to eleven full page plates. There are three appendices on Analyses of Coagulants, Standard Solutions, and Specifications for Lime, Soda Ash and Aluminum Sulphate, in addition to the following table of contents:

Chapter—

I—Water and Its Impurities.
II—Types of Purification Plants.
III—Physical and Chemical Tests.
IV—Bacterial Tests.
V—Interpretation of Tests.
VI—Coagulation and Sterilization.
VII—Water Softening.
VIII—Sedimentation.
IX—Filtration and General Operation.

Field Engineering, A Handbook of the Theory and Practice of Railway Surveying, Location and Construction. By William H. Searles and Howard Chapin Ives. 17th Edition. John Wiley & Sons, Inc., New York. 323 pages. Price $3.00.

The reviewer is one of the many engineers who was "brought up" on Searles and whose only grievance against it was that the author refused to treat of reversed curves, stating in the original preface that "No discussion of reversed curves is given, because these are inconsistent with good practice, except in turnouts, under which head they are noticed." This omission has been remedied, the authors recognizing that reversed curves are necessary in yard work, in cities and other congested places, particularly around buildings in industrial plants. Numerous other additions and changes have been made,

requiring a resetting of the entire text. These changes increase the book by about 150 pages.

Chapter III, the "Theory of Maximum Economy in Grades and Curves," has been rewritten, taking into consideration late investigations on train resistance and also some of the recommendations of the American Railway Engineering Association. The chapters on the Spiral Curve, Earthwork Tables, Earthwork Diagrams, Haul and the Mass Diagram, Calculation of Earthwork and Turnouts and Crossings are nearly or entirely new. New chapters on Cross-sections, Construction and Track Laying take the place of the old chapter on Construction.

Notwithstanding the large amount of additional material, the book is not quite as thick as the reviewer's old copy, the difference being due to thinner and more suitable paper.

The tables, as is well known, extend much farther than in most field books and they are issued separately for those who desire them. Years ago the reviewer had his tables bound separately for convenience and is, therefore, of the opinion that this innovation will meet with favor.

The contents of the book, exclusive of the very complete tables, are as follows:

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, February 7, 1916.

An extra meeting (926), in the interests of the Hydraulic, Sanitary and Municipal Section, was called to order at 7:30 p. m., Monday, February 7, 1916, with about forty-five members and guests in attendance, and Mr. Geo. C. D. Lenth, Chairman of the Section, in charge.

The election of officers of the Hydraulic, Sanitary and Municipal Section was held, which resulted in the unanimous election of the following officers to serve during the year 1916, and until their successors are appointed:

W. W. DeBerard................................Chairman
W. T. Barnes..............................Vice-Chairman
H. E. Hudson..................................Director
R. M. Yager...................................Director

President Grant announced the appointment of several special committees, among them being a Reception Committee and an Excursion Committee and that another committee on New Members would be announced very shortly. He also called attention to the fact that the officers for the Bridge and Structural Section would be ballotted for on February 14th, and that Judge Cutting would deliver an address before the society on February 21st.

There being no further business to come before the meeting, President Grant introduced Mr. Richard T. Fox, General Manager, Citizens' Street

Cleaning Bureau, who presented his address on "Intensive Street Cleaning Methods," illustrated with lantern slides. Discussion followed from Messrs. W. E. Williams, F. H. Bernhard, A. W. Miller, S. A. Greeley, F. J. Postel, J. W. Lowell, J. W. Mabbs, S. E. Bates, J. L. Jacobs, W. W. DeBerard, E. N. Layfield and W. J. Galligan, with explanations by Mr. Fox. Meeting adjourned at 10:30 p. m.

Extra Meeting February 14, 1916.

An extra meeting (927), in the interests of the Bridge and Structural Section, was called to order at 7:30 p. m., Monday, February 14, 1916, with about ninety-five members and guests in attendance, and Mr. H. C. Lothholz, chairman of the section, in the chair.

The election of officers for the section was held by ballot, which resulted in the election of the following officers to serve during the year 1916:

Walter S. Lacher	Chairman
Norman M. Stineman	Vice-Chairman
Frederick G. Vent	Director
Oscar F. Dalstrom	Director

Mr. Walter S. Lacher, the newly elected chairman of the Bridge and Structural Section, then took the chair and introduced Professor Herbert Fisher Moore, Research Professor of Engineering Materials, University of Illinois, who presented his paper on "Stresses in Webs and I-Beams," illustrating his talk by means of lantern slides and charts. Discussion followed from Messrs. Walter S. Lacher, Prof. O. H. Basquin, I. F. Stern, James W. Pearl, M. D. Kolyn, and Mr. James A. Cook, with a closure by Prof. Moore. Meeting adjourned at 10:30 p. m.

Extra Meeting, February 21, 1916.

An extra meeting, No. 928, was held on the eve of Washington's birthday. The meeting was called to order at 8 p. m. by President Grant, with about two hundred members and friends, including many ladies, present.

Mrs. E. N. Layfield sang several songs, after which President Grant introduced the speaker of the evening, Judge Charles S. Cutting, who delivered an eloquent address on "George Washington."

Mrs. Layfield closed the program with "The Star Spangled Banner."

The rooms were draped with large American flags and a picture of Washington hung over the platform.

The meeting adjourned at about 10 p. m.

Extra Meeting, February 28, 1916.

Meeting No. 929. Joint meeting with the Chicago Section of the American Institute of Electrical Engineers and the Chicago Section of the Illuminating Engineering Society.

The meeting was called to order at about 7:45 p. m. by Mr. C. A. Keller, chairman of the Electrical Section, Western Society of Engineers, with about eighty members and guests present.

The general subject for the program of the evening was "Street Illumination." Three papers were presented as follows:

"Recent Street Lighting Problems and Developments," by Mr. J. R. Cravath, M.W.S.E., Consulting Illuminating Engineer; "Some Experiences and Tests in Connection with Chicago Street Lighting," by Mr. A. C. King of the Department of Gas and Electricity, city of Chicago; "Street Lighting Plans of Milwaukee," by Mr. F. A. Vaughn, engineer, Milwaukee Street Lighting Survey.

The papers were discussed by D. W. Roper, Ward Harrison, C. A. Keller, Mr. Shaw and the authors.

The meeting adjourned at about 10:30 p. m.

E. N. Layfield,
Secretary.

Journal of the
Western Society of Engineers

Vol. XXI. MARCH, 1916 No. 3

THE WEB STRENGTH OF I-BEAMS AND GIRDERS

Prof. H. F. Moore.

Presented February 14, 1916.

This paper gives a brief description of a series of tests on the web strength of I-beams and girders made by the Engineering Experiment Station of the University of Illinois. The work had its inception in the discussion of the test results of Marburg* and of Turneaure.† This investigation is one of a number which have been undertaken as a result of suggestions from practicing engineers, and of discussions in the meetings of technical societies and in the technical press. The equipment of the station laboratories, the energies of the station corps of investigators, and the funds available for station work are taxed to the utmost in carrying on the various engineering investigations now in progress. The station is endeavoring to serve the engineering interests of the state and the country, and the interest of practicing engineers and of technical societies and also suggestions as to the work of the station are warmly welcomed.

Bulletin 86 of the Engineering Experiment Station of the University of Illinois, which is now in press, gives a detailed account of the tests of I-beams and girders, and a mathematical discussion of the stresses and strains.

A brief discussion of various ways in which an I-beam or a girder may fail will be given; this will be followed by a general description of the tests made by Prof. Wilson and the writer, with a summary of the test results.

In general, the design of a girder is based on the consideration of the maximum tensile stress and the maximum compressive stress set up in the outer fibers of the flange at the section of maximum bending moment, and on the shearing stress set up in the web at the neutral axis in that cross-section of the girder where the ex-

*"Tests of I-beams," Proceedings of the Am. Soc. for Testing Materials, 1909, p. 409.

†Journal of Western Society of Engineers, 1907, p. 788.

ternal shear is a maximum. The common formulas for investigating these stresses are:

$$S = \frac{Mc}{I} \qquad \text{.......................................(1)}$$

$$S_s = \frac{V}{It} a, c \qquad \text{.......................................(2)}$$

or approximately for I-beam girders

$$S_s = \frac{V}{a_w} \qquad \text{.......................................(2a)}$$

In the above equations:

S = fibre stress in the outer fibres of the flange (lb. per sq. in.).

S_s = fiber stress in shear at the neutral axis of the girder (lb. per sq. in.).

M = bending moment at cross section considered (pound-inches).

c = distance from neutral axis to outer fibers of flange (inches).

I = moment of inertia of cross-section of girder (inches 4).

V = external shear at cross-section considered (pounds).

t = thickness of web of girder (inches).

a, c = "static moment" of part of cross-section above neutral axis (inches).

a_w = area of cross section of web (square inches).

Fig. 1 shows the location of the maximum stresses determined by equations (1) and (2) for a beam under uniform load, and Fig. 2 shows the location for a beam with concentrated load. It should

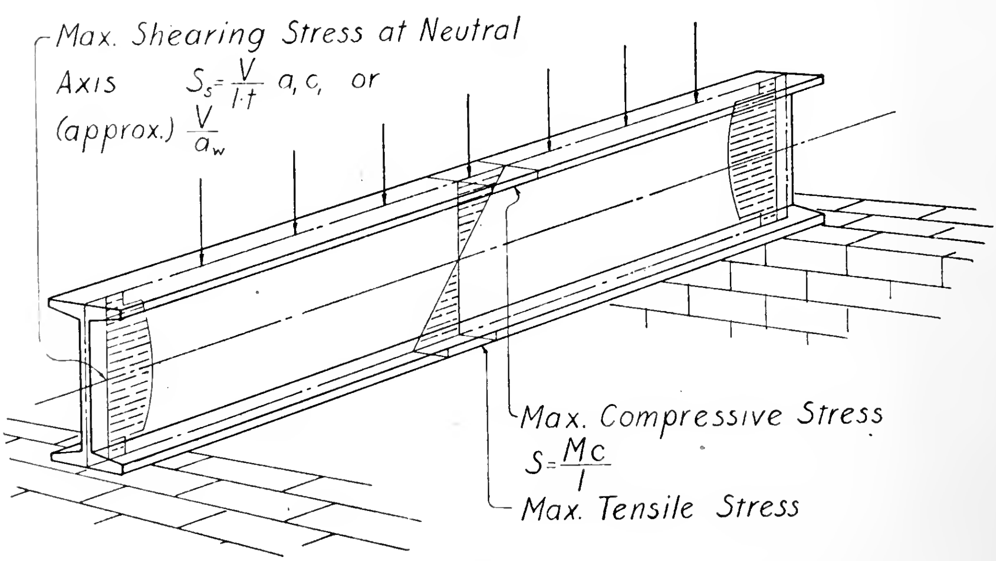


Fig. 1.

be noted that for beams with concentrated loads high bending moment (M) and high shear (V) occur at the same cross-section. This means that for such a cross-section a particle near the root of the flange is subjected to high tensile (or compressive) stress and also to high shearing stress. This suggests that the resulting maxi-

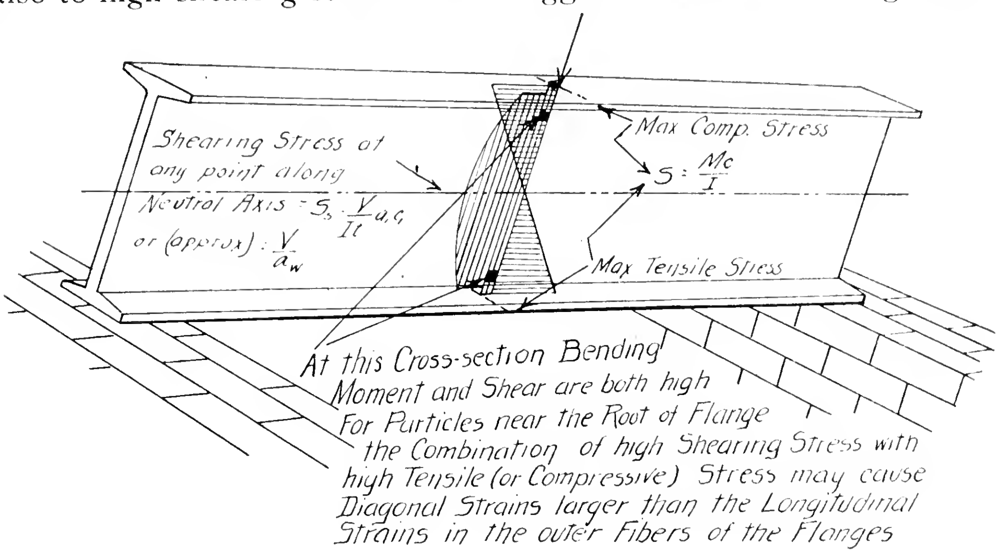


Fig. 2.

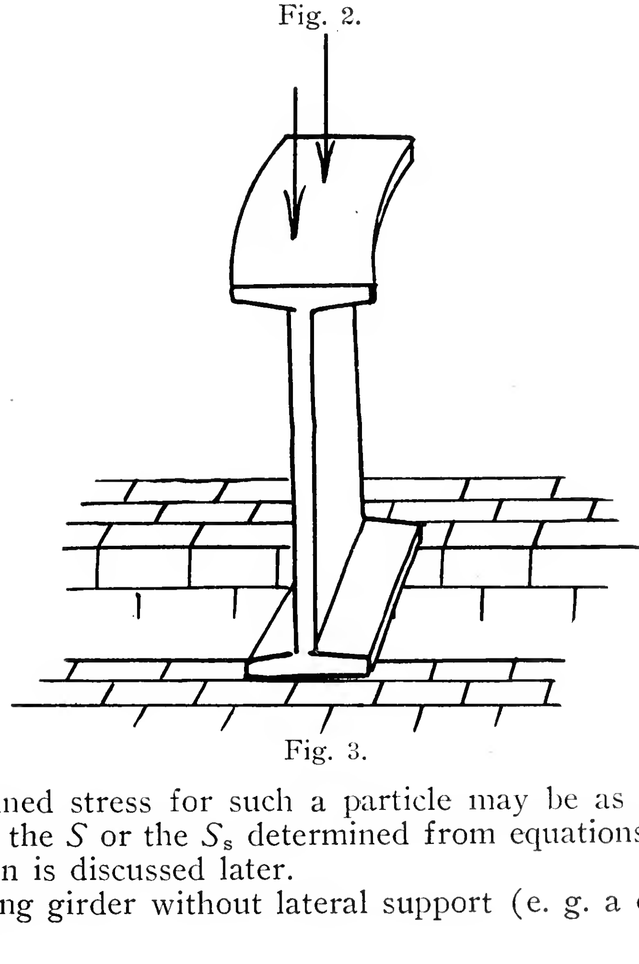


Fig. 3.

mum combined stress for such a particle may be as high or even higher than the S or the S_s determined from equations (1) or (2). This relation is discussed later.

In a long girder without lateral support (e. g. a crane girder)

there is a tendency for the compression flange to buckle sidewise under column action as shown in Fig. 3. This side-wise buckling action is discussed in detail in Bulletin 68 of the Engineering Experiment Station of the University of Illinois, and the following relation is derived from test results:

$$S_e = 40{,}000 - 60\frac{ml}{r'} \qquad (3)$$

S_e = extreme fiber stress $(\frac{Mc}{I})$ which causes failure by side-wise buckling for steel beams (lb. per sq. in.).

l = length of span (inches).

r' = radius of gyration of cross-section of beam about an axis in the plane of the load (vertical axis for beam shown in Fig. 3.) (Inches.)

m = a constant which has the following values:

Simple beam, uniform load, $m = 0.667$.

Simple beam, single concentrated load at any point in span, $m = 0.500$.

Simple beam, equals loads at third points, $m = 0.667$.

Simple beam, equal loads at quarter points, $m = 0.750$.

Simple beam, equal loads at sixth points, $m = 0.833$.

Cantilever beam, uniform load, $m = 0.667$.

Cantilever beam, end load, $m = 1.000$.

Fixed-ended beam, uniform load, $m = 0.281$.

Fixed-ended beam, mid-point load, $m = 0.250$.

In an I-beam or girder the magnitude of the tensile or compressive stress for a particle at the neutral axis along a 45-degree line (in the plane of the web) is the same as the magnitude of the shearing stress (S_s) given by equation (2), which exists in a horizontal direction and also in a vertical direction. The presence of a compressive stress along a 45-degree line tends to cause failure by the buckling of the web as shown in Fig. 4. This buckling tendency is of importance in beams with thin or deep webs and was investigated in the present series of tests.

Over the bearing blocks at the ends of a girder or under concentrated loads there may be set up local compressive stresses which extend into the web of the girder. If the material near the junction of web and flange is stressed beyond the yield point the resultant yielding causes the folding over of the ends of the girder as shown in Fig. 5. This sort of failure, due to excessive compression in the web near a bearing block, was also investigated in the present series of tests.

In the experimental study of the web strength of I-beams and girders two general methods of investigation were used:

1. Tests to failure; in which the loads carried at failure by

various test specimens were measured, manner of primary failure observed, and the corresponding stresses computed by the use of proposed formulas. The reliability of the proposed formulas was judged by the agreement or disagreement of the computed stresses

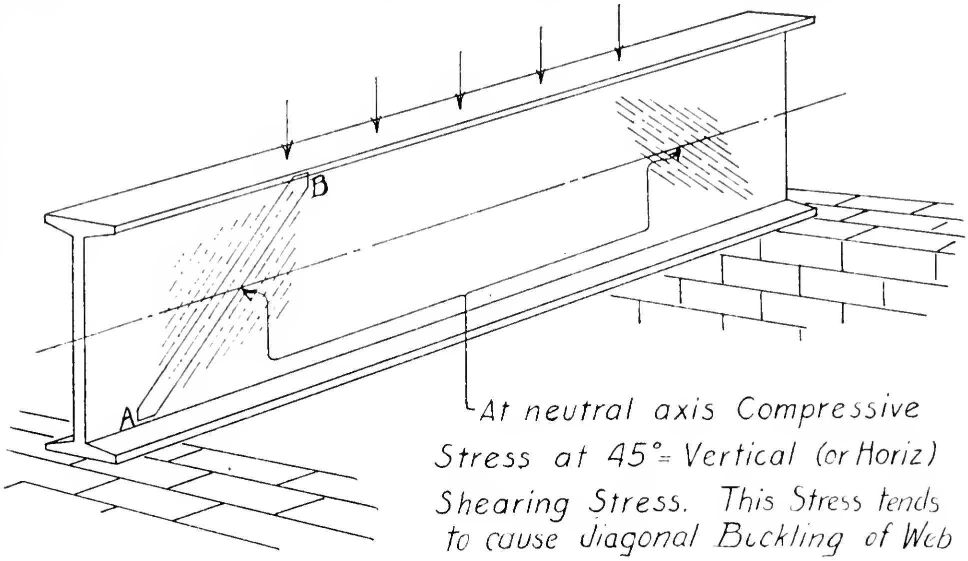


Fig. 4.

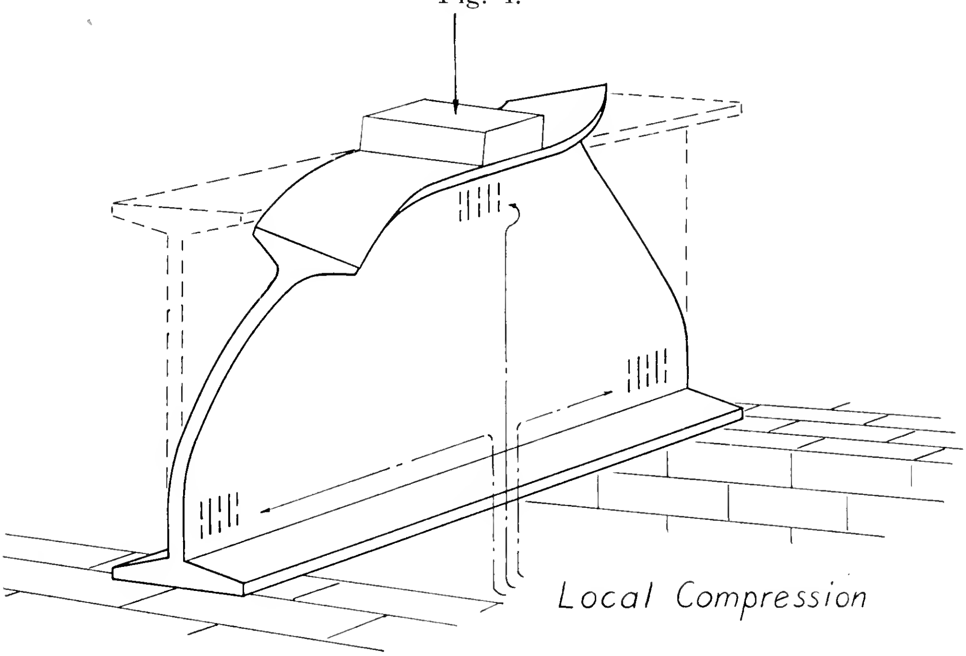


Fig. 5.

with the strength of the material, which was ascertained by tests of test pieces cut from unstressed portions of the test specimens.

2. By the comparison of computed and measured *strains* in the test specimens. (The term *strain* throughout this paper is used to denote deformation.)

In designing specimens for tests to failure, if web failure is to

be studied, it is necessary to make the webs relatively weaker than the flanges in order to make sure that the primary failure will be a web failure, not a flange failure by direct flexural stress. The webs of all the specimens tested were made thinner than standard practice would dictate.

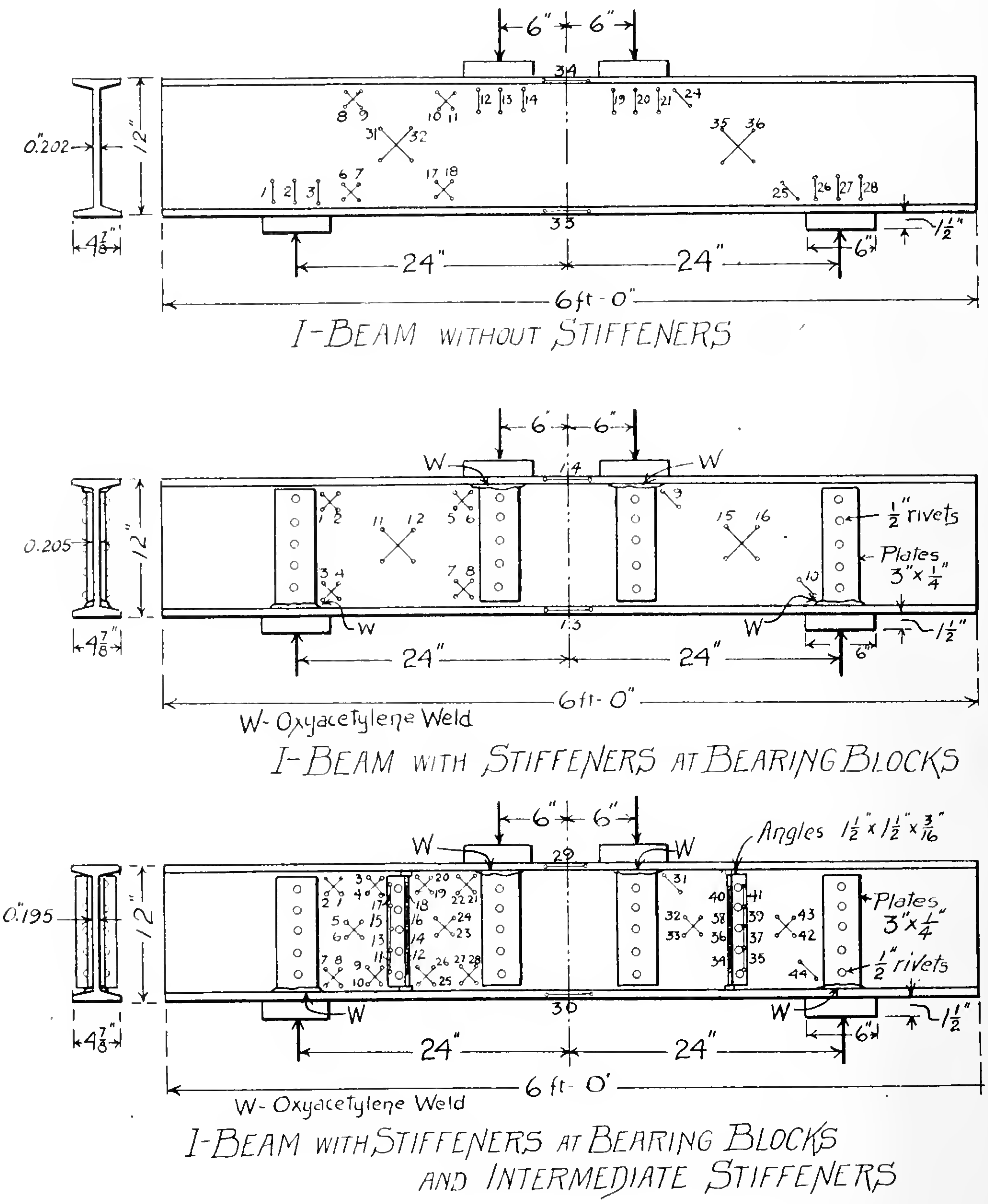


Fig. 6.

The test specimens for the series of tests made by Prof. Wilson and the writer comprised:

1. Six 12-inch, 31.5-lb. I beams with webs planed thin. Two of these I beams had no stiffeners of any kind; two had end stiffeners and stiffeners under load points; two had end stiffeners and load point stiffeners, and in addition, intermediate stiffeners to pre-

vent buckling of the webs. These I beam specimens are shown in Fig. 6.

2. Two 24 inch built up girders with thin webs. One of these

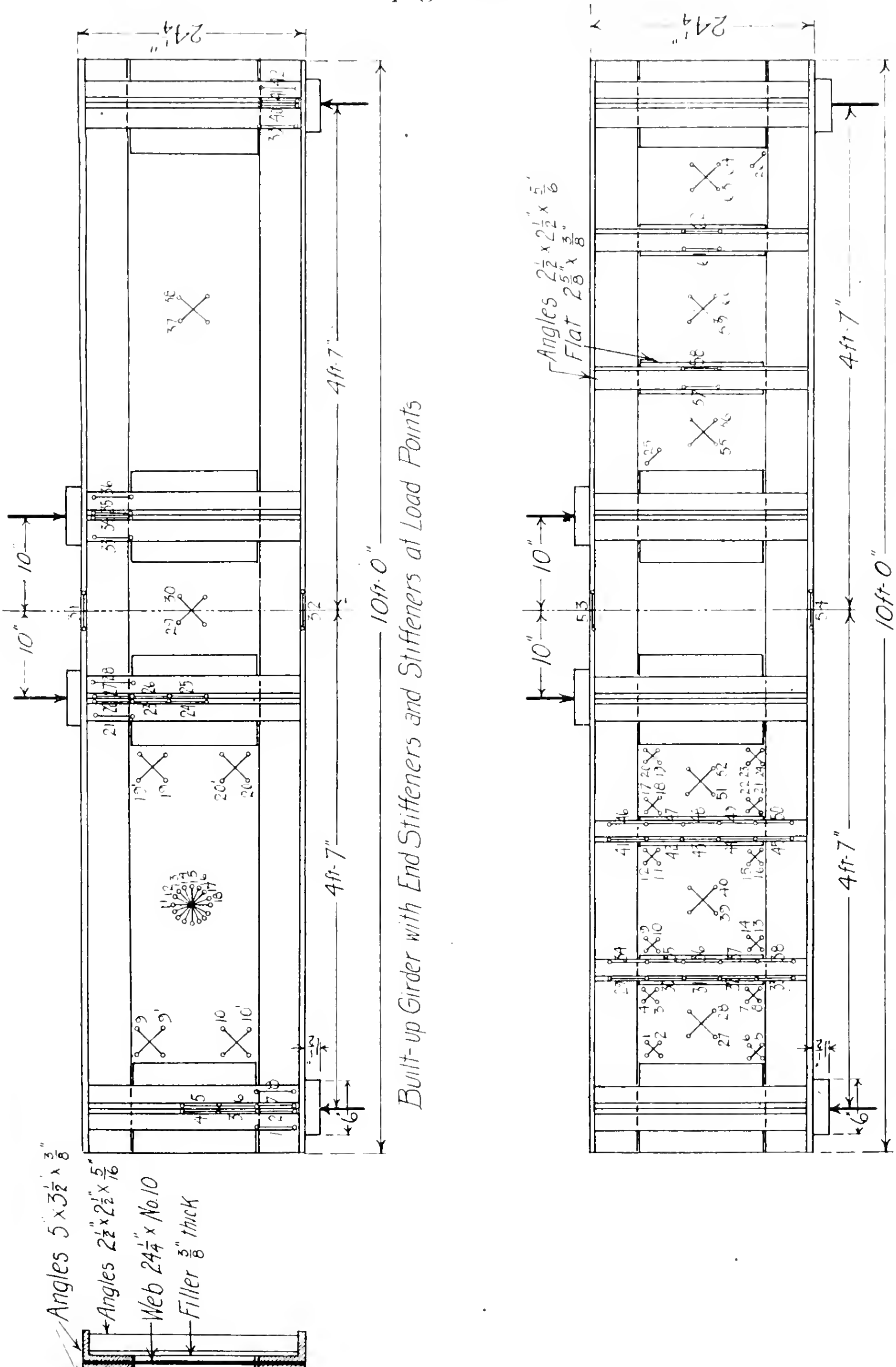


Fig. 7.

girders was fitted with stiffeners for supports and for load points; the other was fitted with stiffeners for supports and load points, and

in addition, with intermediate stiffeners. These girders are shown in Fig. 7.

All test specimens were loaded with two equal loads at points symmetrical with the mid-point of the span. This method of loading gives uniform bending moment over the portion of the test specimen between loads (neglecting the weight of the test specimen). The tests were made in a 600,000-lb. Riehle vertical screw testing machine.

Strains in various portions of the test specimens were measured with a Berry strain gage.* Figs. 6 and 7 show the location of the short gage lines along which strains were measured for the test specimens. In Figs. 6 and 7 each gage line is indicated by two small circles joined by a straight line, and is given an identifying number. For each gage line on one side of a test specimen there was a mating gage line on the other side.

The procedure for each test was as follows: Load was applied by increments of suitable amount, and for each increment of load readings of the strain gage for each gage line were taken, and also readings of the deflection of the test girder at mid-span. The load was increased until the test specimen collapsed, and the maximum load carried was noted.

The strains observed along certain of the gage lines were compared with the strains as computed by the mathematical theory of strain. Fig. 8 shows the plotted results of strain measurements for a typical test. In computing these strains allowance was made for the effect of stress at right angles to any gage line; in other words, Poisson's ratio was taken into account. The values used for Poisson's ratio was 0.3. In general, there was an excellent agreement between observed strains and computed strains. On 163 gage lines comparisons were made, and for 107 of the gage lines the agreement was within 10 per cent; of the remaining 56 gage lines 40 were near concentrated loads, where local stress was high; for the remaining 16 gage lines local bending was present as shown by the widely differing strain on the two sides of the test specimen.

Having obtained a satisfactory verification of the elastic formulas for compound stress, the *maximum* stresses and strains occurring under any loading may be computed.*

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*For a detailed description of the strain gage and of methods of using it see Bulletin 64 of the Engineering Experiment Station of the University of Illinois, and Proceedings of the American Society for Testing Materials for 1913, p. 1019.

*A fuller discussion of the elastic formulas for strain is given in Bulletin 86 of the Engineering Experiment Station of the University of Illinois. The formulas for combined stress may be found in any text on Mechanics of Materials, such as Merriman, Morley, Murdock, Church or Boyd. Lanza's "Applied Mechanics" gives an excellent treatment of the subject of strain under combined stress.

Applying the elastic formulas for compound stress to various typical cases of loaded beams some interesting results are obtained.

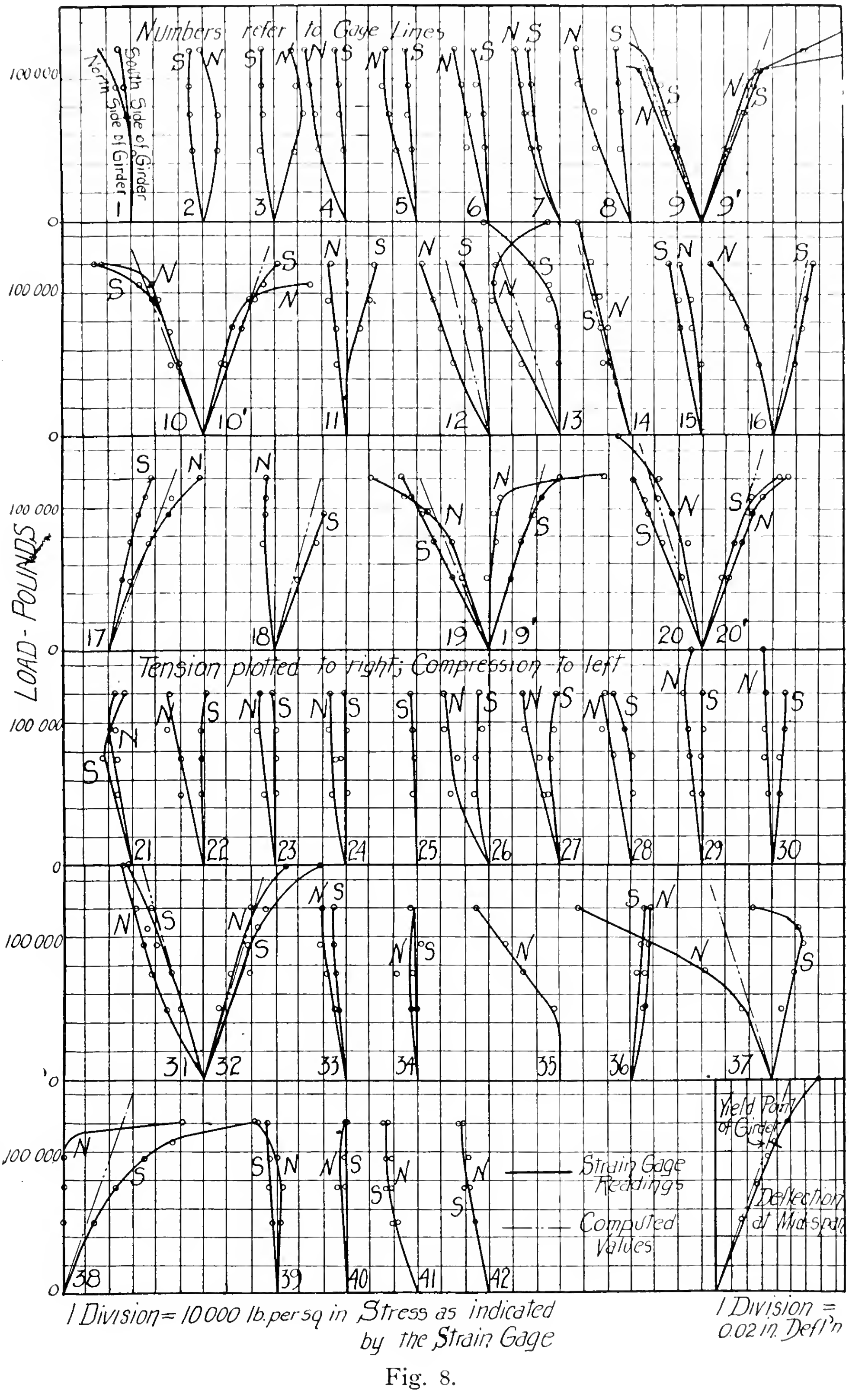

Numbers refer to Gage Lines
South Side of Girder
North Side of Girder
100 000
LOAD - POUNDS
Tension plotted to right; Compression to left
Strain Gage Readings
Computed Values
Yield Point of Girder
Deflection at Mid-span
1 Division = 10 000 lb. per sq in Stress as indicated by the Strain Gage
1 Division = 0.02 in. Defl'n

Fig. 8.

The maximum shearing stress may be not at the neutral axis, but may be at the junction of web and flange near a concentrated load. However, after making computations for a large number of typical cases it was found that the excess of shearing stress at junction of web and flange over the shearing stress at the neutral axis was not over 3.5 per cent for the worst case examined, and that in this case the shearing stress was low in comparison with the flexural stress, and hence was not a criterion of strength. In this connection it was found that the approximate method of obtaining shearing stress [See equation (2a)] gives results which in some cases may be 20 per cent lower than are given by the more exact formula [equation (2)]. It would seem that in designing a girder it would not be necessary to compute the diagonal *shearing* stresses at the inner edge of the flange, but that if the approximate formula (2a) is used it should be checked by the use of the more exact formula (2) if the approximate shearing stress is found to be more than 80 per cent of the allowable shearing stress.

By applying the elastic formulas to a number of typical cases for beams and girders in which the flexural stress and the shearing stress are both high, it is found that the maximum diagonal strains near the junction of web and flange may be 20 to 25 per cent higher than the longitudinal strain in the extreme fibers of the flanges which strain corresponds to the stress given by the common flexure formula, equation (1). For beams carrying concentrated loads, designed to develop high stresses both in flanges and in the web, the diagonal strains at the root of the flanges should be computed. Bulletin 86 of the Engineering Experiment Station of the University of Illinois gives a detailed account of all these tests; it also gives examples of the application of the elastic formulas for the determination of both shearing stresses and diagonal tensile (or compressive) strains set up by the combined action of shear and bending moment.

Considering now the loads carried by the test specimens at failure there are found some data for the study of web buckling and compression over bearing blocks. It is not altogether easy to say at what point failure occurs in a test of a beam. As load is increased there are first noted signs of local distress. Frequently such local damage is due to imperfections in material or to local bending, and is shown by the flaking off of mill scale. For static loads it is probable that such local damage, if confined to a small area, is of little account; for repeated and reversed stresses local overstress may start a crack which, spreading, may cause final failure of the whole girder.

In the lower right hand corner of Fig. 8 is shown a typical load-deflection diagram for a girder test. There is seen to be a fairly well-marked "break" in the curve. This "break" seems to mark the beginning of general yielding of the girder and the stress at this point has been called the *yield point of the girder*. Beyond the yield

point of a girder the load increases slowly to an ultimate value under which the girder collapses. Under long-continued dead load the girder would, in all probability, collapse at some load between the yield point and the ultimate as found in a testing machine test. In view of the fact that, if stressed beyond the yield point, the girder

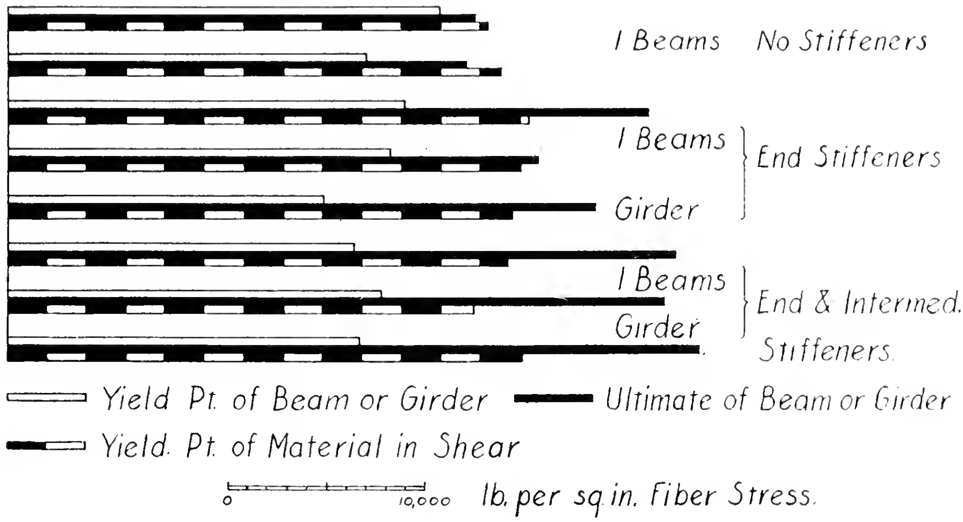


Fig. 9.

would be badly distorted, it seems advisable to regard failure of the girder as occurring at the yield point.

In considering failure of a beam or girder by shearing stress in the web it must be remembered that the yield point of steel in shear is about 0.6 of the yield point in tension. Fig. 9 shows the shearing stress (computed by the use of equation 2) developed at the yield

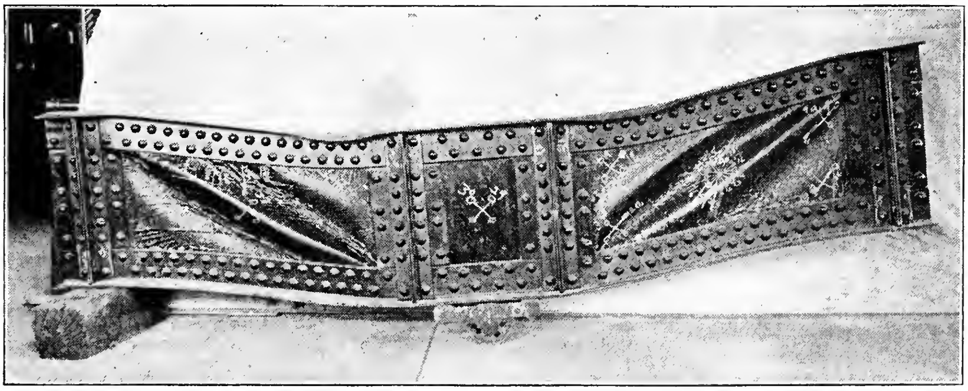


Fig. 10.

point of the test beams and girders and at the ultimate (maximum load carried.) In every case the yield point of the girder was reached at a shearing stress less than the yield point of the material in shear, but in all cases except for test beams without any stiffeners before final collapse (ultimate) was reached the yield point of the material

in shear was developed. The beams without stiffeners failed primarily on account of excessive compression in the webs over bearing blocks. In none of the tests could shearing stress in the web be regarded as the primary cause of failure, nevertheless complete collapse did not take place (with the exceptions noted above) until the yield point strength of the material in shear was developed.

Buckling of web was the primary cause of failure for the test specimens with stiffeners. Fig. 10 shows one of the built-up girders after failure, and in this cut the wrinkling of the web can be seen plainly. In several texts on Mechanics of Materials the method of computation for buckling strength of web is an approximate method, and is based on the mathematical relation that along a 45-degree line the compressive stress at the neutral axis is numerically equal to the vertical or horizontal shearing stress. A narrow strip of web inclined 45 degrees with the vertical (See AB, Fig. 4) is considered as a fixed-ended column carrying an average compressive fiber stress equal (numerically) to the shearing stress at the neutral axis as computed by equation (2). The length of this column is, then, the depth of web between flanges multiplied by the secant of 45 degrees, or if h is this depth of web the length of column becomes h sec $45°$ or $h\sqrt{2}$. As the web is usually thin, Euler's column formula may usually be used (though Rankine's formula would do as well). Euler's formula for fixed-ended columns is:

$$S_b = \frac{4\pi^2 E}{\left(\frac{l}{r}\right)^2} \qquad (4)$$

in which S_b = the average compressive fiber stress for failure of the column by buckling (lb. per sq. in.).

E = the modulus of elasticity of the material (lb. per sq. in.) (30,000,000 for steel approximately).

l = the length of the column (inches).

r = the minimum radius of gyration of the cross-section of the column (inches).

If l in the equation (4) is replaced by $h\sqrt{2}$ and r by $\frac{t}{\sqrt{12}}$ (h is the depth in inches of the web between flanges, and t, the thickness of web), the equation for buckling strength becomes:

$$S_b = \frac{1.64E}{\left(\frac{h}{t}\right)^2} \qquad (4a)$$

Fig. 11 shows the agreement between the proposed formula for web buckling (equation [4] or [4a]) and the test results for yield point of test beams and girders. For the I beams the agreement is fairly close; for the built-up girders the heavy stiffeners at supports and at load points apparently served to stiffen the girder webs against buckling. The results of Turneaure showed the same stiffening action for end stiffeners. For both the I beams and the built-up

girders with intermediate stiffeners the yield point was but slightly increased over the yield point for the test specimens without intermediate stiffeners. Remembering that the primary cause of failure of the I beams without any stiffeners was local compression over bearing blocks, it will be seen that for all test specimens which failed by buckling of web the use of Euler's formula for fixed-ended columns (equation [4] or [4a]) gave results which were on the safe side, even with stiffeners spaced farther apart than standard practice allows. This method of figuring the buckling strength of webs seems to be safe. However, if the value of S_b is found to be higher than the safe *shearing* stress, the latter governs the design.

The actual distribution of local compressive stress in the web of a girder near a bearing block is decidedly complex. A simple approximate analysis by C. W. Hudson* seems to give results which are in fair agreement with tests. Fig. 12 shows the portion of an I beam over a bearing block cut away from the remainder of the

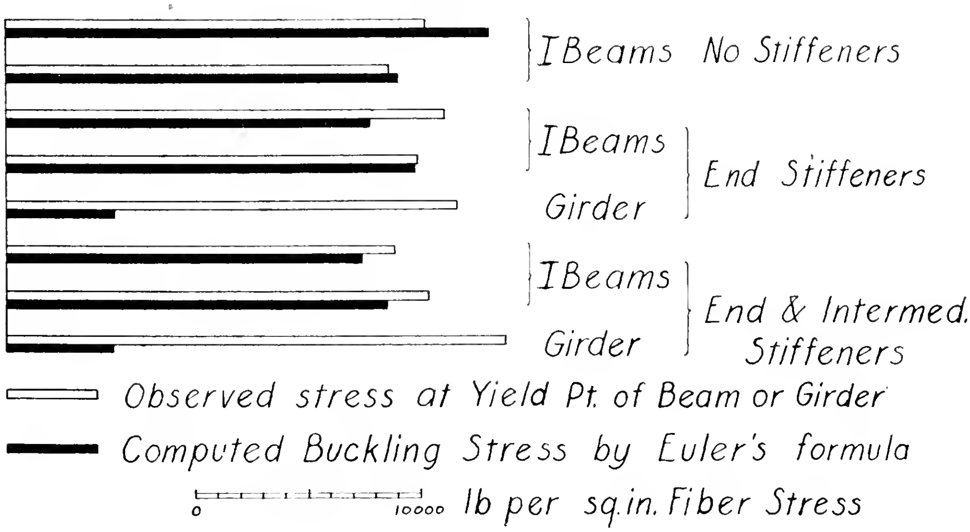


Fig. 11.

beam along a line near the junction of web and flange. This particle is shown held in equilibrium by the forces acting on it when it is a part of the beam. Assuming that the compressive stress (vertical) on the web is uniformly distributed the summation of the vertical forces gives:

$$P - S_w bt - V_v = O$$

in which P = concentrated load or reaction on bearing block (pounds).

S_w = local compressive stress in web (lb. per sq. in.).

b = length of bearing block (inches).

t = thickness of web (inches).

V_v = the part of the vertical shear carried on the cross-section of the part shown cut away from the beam.

*Engineering News, Dec. 9, 1909.

If the stress at the root of the flange is to be considered, V_v may be neglected since nearly all the shear for a cross-section of the I beam is carried by the web. If V_v is neglected, the formula for S_w becomes

$$S_w = \frac{P}{bt} \qquad (5)$$

which is Hudson's formula.

As previously noted, in the tests of the I beams without stiffeners the primary cause of failure was local compression over bearing

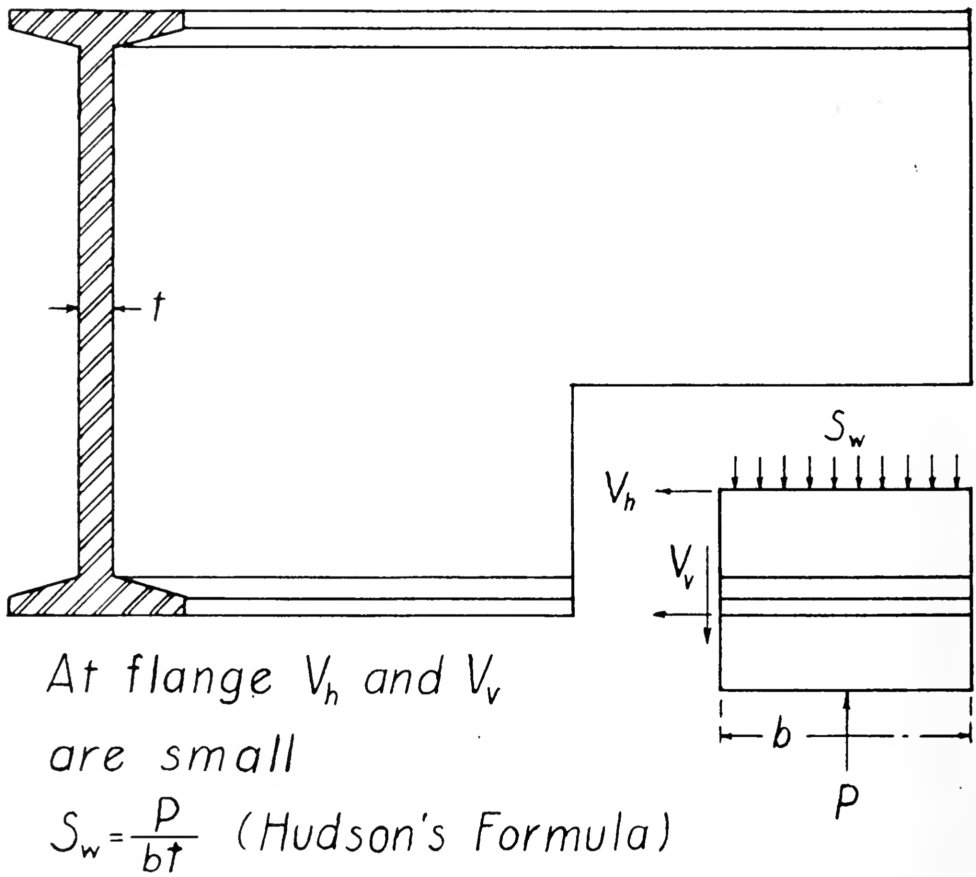


Fig. 12.

blocks; this seemed to be the case also for one of the beams tested by Marburg and for several beams tested previously at Illinois.* Fig. 13 shows the agreement between the local compressive stress at failure of the beam as given by Hudson's formula and the yield point strength of the material at the root of the flanges of the I beams as shown by tests of specimens. The agreement is fairly close, and in the cases where the divergence of results is widest, Hudson's formula gives results which are on the side of safety. In using Hudson's formula it should be borne in mind that the steel

*Bulletin 68, Eng. Expt. Station, Univ. of Ill., p. 33.

at the root of the flanges of I beams is generally weaker than the steel in the flanges or in the web. The allowable stress for steel at

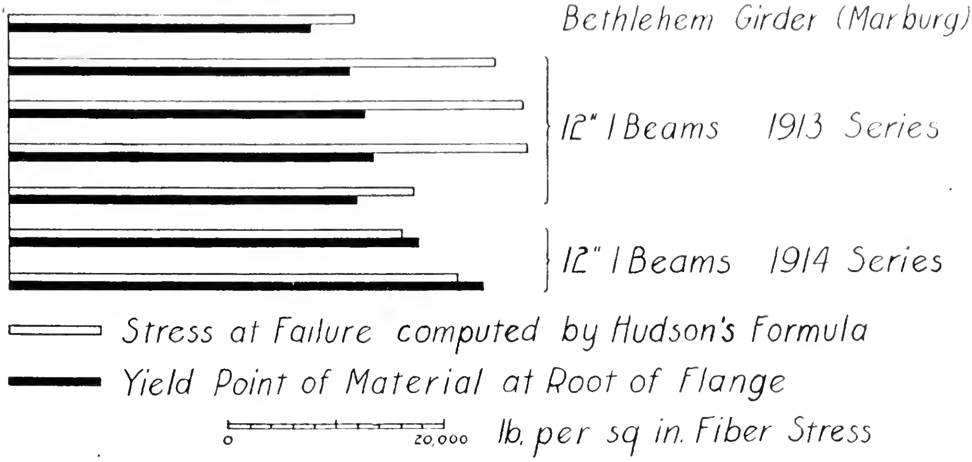


Fig. 13.

the root of the flanges should hardly be taken higher than 85 per cent of the allowable stress for the steel in the flanges.

In applying Hudson's formula to girders with stiffeners at

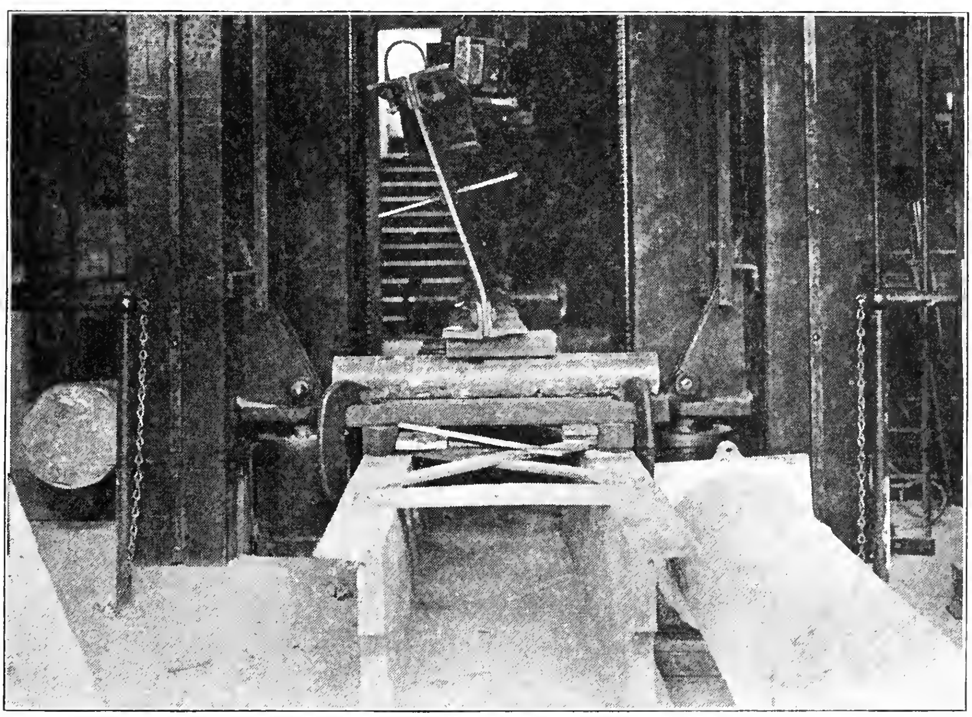


Fig. 14.

supports and at load points, the area under compression would not be *bt*, but would include the area of cross-section of the stiffeners.

Fig. 14 shows a characteristic failure of a girder due primarily

to local compression over a bearing block. This girder is not one of those shown in Fig. 7.

The stresses set up in the stiffeners of the test specimens are of interest. Fig. 15 gives average load-stress diagrams both for intermediate stiffeners and for stiffeners at load points and supports. In the intermediate stiffeners there is not much stress until the yield point of the girder is reached, in the load point stiffeners, and the end stiffeners, on the other hand, stress comes on fairly regularly with load, though some end stiffeners get very little stress. The function of intermediate stiffeners seems to be to provide insurance against disastrous web collapse rather than to carry stress under

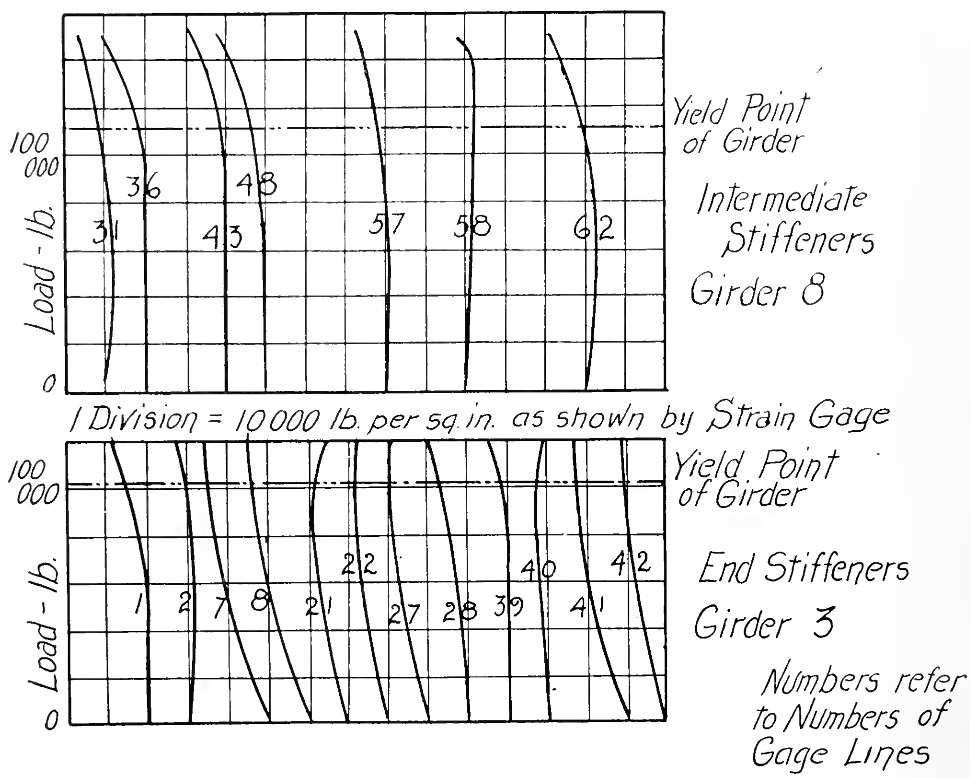


Fig. 15.

working loads. Load point stiffeners and end stiffeners, on the other hand, under working loads carry stress from concentrated loads or reactions and thus relieve the local compressive stress in the web. The general results of the tests emphasize the importance of stiffeners at ends and load points, and the necessity of securing good bearing between the stiffeners and the flanges of the beam or girder. In the built-up girders the stiffeners were carefully fitted in place; in the I beams tested the end and load point stiffeners were welded to the flanges by means of an oxy-acetylene torch.

Summary.—Diagonal strain due to combined stress in webs of girders near the junction of web and flange may be of importance

for girders with concentrated loads in which both the shearing stress and the flexural stress are high.

The shearing stress in girder webs should not be more than about 0.6 of the allowable tensile stress for steel. Diagonal shearing stress near the junction of web and flange due to combined stress need not be considered, but the approximate method of computing shearing stress (equation [2a]) should be checked by the more exact formula (equation [2]) in case the shearing stress is found to be more than 80 per cent of the maximum allowable shearing stress.

For computing the buckling strength of web under the diagonal compression accompanying shear the approximate method of considering a 45-degree strip as a fixed-ended column, and applying Euler's formula (equation [4] and [4a]) gives results in fair agreement with tests.

Local compression over bearing blocks should be considered. Hudson's formula (equation [5]) seems fairly reliable.

The tests emphasize the importance of stiffeners at load points and at supports, and suggest that the resisting power of thin webs to shearing stress and to buckling has been somewhat underestimated in the past.

DISCUSSION

W. S. Lacher, ASSOC. W. S. E (Chairman): Criticism is often directed against engineering discussion, particularly when it is along a strictly technical line such as the talk we have had tonight, in that it lacks interest largely because the human element is absent. We do not have the human interest that obtains in talks on what some people like to term broader subjects. I do not think that has been the case tonight. I am sure we have all enjoyed this talk very much, and, in a way, there is some human interest connected with it from the standpoint of the man who has studied structural engineering. After he had been thoroughly drilled in the formula

$$S = \frac{MC}{I}$$

and when he learned that unit shear is obtained by dividing the end shear by area of the web, the chances are that the average novice in structural engineering thought he had learned everything that it was necessary to know about the theory of bending, and it was all very clear to him; but as he grows older he learns that it is not so easy. Different things are brought to our attention which show that what takes place inside of a beam due to an applied load is something more complex than we had originally supposed, and I think Professor Moore at least has made clear to us that the stress action is very complex.

O. H. Basquin, M. W. S. E.: Professor Moore has referred to Hudson's formula for the compressive stress on horizontal sections of a beam that is carrying distributed loads on its upper flange. I suppose that reference is made to page 30 of Hudson's *Plate Girder*

Design. This formula is correct, but it is not stated in a form that shows how this stress varies for beams of different cross-sections: the ordinary expression for the shearing stress is much more convenient than it would be if stated as a difference of two forces divided by an area, and so we can put the Hudson formula into a shape that will correspond to that for shearing stress.

Let a beam be carrying a distributed load w, per unit length; at one section the shearing force (vertical shear) is Q, while at a section distant dx at the right shearing force is $(Q - w\ dx)$. At a point in the first section at elevation y above the neutral axis the shearing stress in the vertical section is given by the ordinary formula as

$$q = \frac{Q}{I.b} \int_{y}^{y} y.dA = \frac{Q}{I.b} k.$$

In the right-hand section (distant dx from the first), the shearing stress at the same elevation is less than the above value by

$$\frac{w.dx}{Ib}.k$$

Now, if we consider an element of volume whose length is dx, whose width is b (the width of the beam at this elevation), and whose height is dy, the area of each end face is $b\ dy$; the above difference of shearing stress on the *two* end faces gives an upward force on the element of volume whose value is

$$\frac{w.dx}{I} k.dy;$$

and the compressive force upon the upper face of the element of volume must be larger than that on the lower face by this same amount. At the lower face of the beam there is no compressive force. If y_2 is the ordinate of the lower face and y_1 that of the upper face, the compressive stress on a horizontal element (area $b\ dx$) distant y above the neutral axis will be given by either of the expressions

$$\frac{w}{I.b} \int_{y2}^{y} k.dy = \frac{w}{b}\left(1 - \frac{1}{I} \int_{y}^{y1} k.dy\right)$$

While this expression is perfectly definite, there is some difficulty in evaluating the integral for beams of other than rectangular cross-section. It is not difficult to show that it can be thrown into the following form, although time will not be taken here to give the demonstration:

$$\frac{w}{b}\left(\frac{I'}{I} + \frac{k.y}{I}\right)$$

in which I' is the moment of inertia about the neutral axis of all portions of the section whose ordinates are not greater than y.

In the case of an I beam about 95 per cent of the load on the upper flange enters the upper edge of the web as a compressive

stress. At the neutral axis half the load has been changed to increments of shearing stresses. At the lower edge of the web about 5 per cent of the load remains as compressive stress on horizontal sections. The disappearance of this stress in the web is by a nearly straight line relation.

The above analysis is based upon the numerous assumptions that are made in the ordinary simple theory of bending, and the result is limited by them. It will not represent facts close to sections at which the shearing force is changing very rapidly, such as under high concentrations, although in such a case an expression like this is better than none. Prichard and Williams have shown (Trans. Am. Soc. C. E., vol. 75) that change in shearing force affects the fiber stresses near such sections. The compressive stress on horizontal sections have a similar effect.

The common theory of bending is of great value in furnishing short solutions to difficult problems. In most cases these solutions are nearly enough correct for practical purposes. However, there are many details of structural design in which the theory is likely to give results that are far from the truth. We have to depend upon such investigations as this of Professor Moore to clear up these details and to make sure to what extent this theory can be depended upon. This work and much other work that has been done in his laboratory is of the highest value in this respect.

I. F. Stern, M. W. S. E.: I was very much impressed with the paper and I could not help thinking after the chairman made the statement that engineering discussions lacked human interest that he was slightly at fault in this case, because if there is anything that has particular human interest, it is the building of structures that are used by humans and over which they pass, for the seeing that they are safe is certainly a very vital thing. It may not appeal as much to the draftsman when he first starts out, but to those in charge of work who have to pass on it, the realization comes very soon after they do get in charge of work, that they have human lives in their charge and that it is quite essential that they follow the work of investigators such as Professor Moore.

In listening to this paper and to other papers which have been presented to the society I am very much impressed by the fact that as a general thing we, who have been working along this line seem to have known in the main what we were doing. As Professor Basquin has said, the general theory of our design is very well corroborated by practical tests. There are some by-ways and some points that are little discussed, but when experiments are made they usually demonstrate that the practical designer has done the right thing. Take, for instance, the development in the tests made by Professor Moore that shear should have a unit stress six-tenths of the unit stress used for tension. When we used to use 10,000 pounds in tension we used 6,000 in shear. Take the A. R. E. A. specifications at the present time. They use 16,000 pounds in tension and

10,000 pounds in shear, which is about sixty-two per cent. It would seem that the writers of those specifications, the Committee on Iron and Steel Structures of the A. R. E. A., apparently knew their subject and knew what they ought to do.

It would seem from Professor Moore's paper that in using our usual formula for unit shear by taking the total shear and dividing by the cross section of the web, it may possibly be necessary to cut down the unit stresses twenty per cent, and that is a point that struck me as the most important of the paper. It may be necessary to go into that matter further than we have gone up to the present time. I do not think it at all possible that we can expect designers to use the more intricate formula for the shear test. If we find that this more intricate formula does in many instances show an increase of twenty per cent, the only practical way to handle the matter is to decrease our unit allowable stress by twenty per cent. We are getting more and more in the way of using simplicity in our stress analysis. About two months ago we had a paper here upon the use of influence lines and the use of the Williot diagram, and it struck me after listening to the paper that it was not necessary to use either of those excepting in very special circumstances; that our simple method of computation used in drafting rooms gave so close an approximation that, only in the type of what is known as higher structures was it necessary to use more elaborate computations. Every time we hear a paper that shows evidence of having gone into the matter from the highest theoretical standpoint and from the standpoint of test, we come again to the same conclusion, that it is proper to make these higher computations and it is absolutely essential to make the physical tests, but both these higher computations and the physical tests should be made with a view of determining what should be used in simpler computations.

Chairman Lacher: Mr. Stern raised a point in the human interest that I overlooked.

A number of years ago—well, not so many—it was when I did my first work on the board outside of school—I was very much surprised in looking over some old computations for the design of a plate girder that had been made before I was born, that there was only a very slight difference between the methods then used and those used at the present time. The method of determining the section was practically the same. The point is that such an investigation as we have heard about tonight is devoted to refinements, to minor details that one is liable to overlook. What some people like to call good judgment, or visual sense of design, may tell you the limit to which you can go in spreading your flange in a rolled beam, but specific tests, such as Professor Marburg reported some years ago, proved conclusively that there is a very definite limit to the amount of flange that can be developed by a given size of web.

There is a question I want to ask Professor Moore. Specifications for workmanship on structural work are based on what we

know about the action of steel under stress and what we consider good judgment or what we think is necessary to get a finished piece of work. Now, referring to such a detail as the need of a perfect bearing for the end stiffener on the flange or whether that is necessary with an intermediate stiffener, could such details, the necessity for such refinement, be worked out in tests of this kind?

Professor Moore: The points just raised were considered in the tests, and had time allowed, a series of tests would have been made with beams with end stiffeners well fitted and with other beams with which the stiffeners were not well fitted. Owing to the importance of the compressive action over a bearing block, it would seem that until we have very definite test data to the contrary that the specification requiring a good bearing between stiffener and flange is important. I do not know whether the oxy-acetylene torch could be applied to insure such bearings in girders, I am not familiar enough with structural shop practice. We found in the case of the I beam stiffeners, which we fitted in place, that the oxy-acetyline torch proved efficient.

Chairman Lacher: How was it used, similar to the method used in welding?

Professor Moore: Yes, a little space was left between the bottom of the stiffener and the flange, and that was simply filled in with soft steel wire, using the oxy-acetylene torch. That ensured a pretty good bearing.

Mr. M. D. Kolyn: In ordinary design we use three-quarter inch sole plate or an inch sole plate, according to the judgment of the designer, underneath the stiffener ends, in order to take the bearing. It always seemed to me that that was pretty thin in there to distribute the bearings over. Did you have a test to show that?

Professor Moore: No.

Mr. Kolyn: Another thing, in your tests, you had to make it thin in order to get the webs sure to fail. We made tests in which we had the standard size of webs and the web showed about the stress shown in your tests. The failure was not complete, but still it had very well marked stress lines.

Mr. James A. Cook: Mr. Chairman: In the case of a very thin web which has a number of closely grouped exploring holes for the strain gauge, the holes being of the magnitude of one-twentieth of an inch in diameter and going half way through the web, is it not true that modifications of the indicated results would have to be made in order to allow for the effect of removing so much metal?

Professor Moore: I think the answer to that could be found in the investigations of Dr. Preuss*; and in this connection I am very sure that all people who have to do with materials testing felt a sense of personal loss when they heard that the director of the materials testing laboratory at Darmstadt was killed "somewhere in

*Zeitschrift des Vereines Deutscher Ingenievre, April 26, 1913, p. 664.

France." Professor Preuss devised extensometers of extraordinary sensitiveness and found that immediately around the holes there was considerable variation in stress; however, the variation did not extend very far. The shortest gage length which was used in tests at Illinois was two inches. The diameter of the hole was one-twentieth of an inch, or perhaps one-fortieth part of the gage length and the disturbing effect would be confined to the immediate vicinity of the gage holes and would not have much effect on the stress over the entire gage line. The gage holes were made as small as possible. Probably variations in the material itself would cause more unevenness of stress distribution than would the irregular action near gage holes.

A Member: A common specification of ordinary design of plate girders is that stiffeners need not be used when the main part of the girder is less than sixty times the thickness of the web. Was there anything in your investigation which would support that specification?

Professor Moore: Our investigation showed that the specification was certainly safe and that probably you could go somewhat beyond the above limit without very serious danger, omitting stiffeners, if the length was eighty or perhaps even a hundred times the thickness of web. Of course under such conditions you will have to be sure that the webs are not in danger of *buckling,* that they are not in danger of failure by *direct shear,* and that they are not in danger of failure by local *compression.*

There are one or two points about which I should like to speak.

The point raised by Professor Basquin about the variation of this stress is a very interesting one and I certainly hope that he can find means of following his investigation further. We have data for seeing if the stress varies in the way he indicated, but I did not bring with me diagrams which will show those particular data.

The question was raised, I think by Mr. Stern, of the excess of shearing stress as given by the exact formula over that given by the approximate formula. The excess of twenty per cent referred to in the paper was for extreme cases; in ordinary cases, as Professor Wilson figured them, it is much more common to find the variation about eight per cent.

I wish emphatically to disclaim any intention to cast any doubts on any ordinary formulas of flexure which we use. They are of course the formulas which we use, have used, and will continue to use in ninety-nine cases out of a hundred; and I, remembering the days when I worked over a drafting board, wish to avoid burdening designers with any unnecessary long formulas. I do hope, however, that these tests of Professor Wilson and myself will cause a questioning attitude on the part of designers, as to various kinds of stresses which may be set up in a beam or a girder and that designers will think qualitatively, if not quantitatively, whether their

beams and girders they are designing are able to resist all such actions.

I feel that there might have been a good deal more "human interest" if the tests had shown that the current practice is wrong and very unsafe. I agree with Mr. Stern that the tests did not show this and, in general, did confirm current practice.

I wish to state to any who may be interested, that a somewhat more detailed account of the investigation is in press now (Bulletin No. 86 of the Engineering Experiment Station of the University of Illinois), and there is one point I wish to make very emphatic, that is, that this investigation is not the sole work of the speaker, but was the joint work of the speaker and Professor W. M. Wilson of the Department of Structural Engineering of the university.

INTENSIVE STREET CLEANING METHODS

STANDARDS OF STREET CLEANLINESS AS DEVELOPED BY THE CITIZENS' STREET CLEANING BUREAU THROUGH TIME STUDIES OF REFUSE DISTRIBUTION, OF TIME ELAPSING BEFORE COLLECTION FROM THE STREET, AND OF OTHER FACTORS IN HAND-SWEEPING OPERATIONS, IN THE CENTRAL BUSINESS DISTRICT OF CHICAGO.

BY RICHARD T. FOX.

Presented February 7, 1916.

A standard of street cleanliness, so far as I know, has never been defined. At least there is no record of it.

Two people will disagree as to which of two cities has the cleanest streets. If there is no prejudice in the minds of either, they may both be right, for their conceptions of what constitutes a clean street may differ. In other words, their standard of cleanliness is not the same. A standard of street cleanliness, then, is a question of individual opinion.

In connection with our work in Chicago downtown streets, we have attempted to create a standard of cleanliness which is a matter of fact—a standard that can be defined and checked.

In order to make clear what is meant by our standard of cleanliness, it is necessary to consider the character and distribution of street refuse and the method of removing it from the streets.

How the Work Is Apportioned.

The process of cleaning the streets is carried out in two operations—one, the collection of the refuse from the streets; two, the removal of the material to the points of disposal.

The latter is a simple transportation problem, involving the hauling of certain quantities which vary somewhat from day to day from definite points, definite distances to the points of disposal. The factors affecting the amount of work a cart, wagon, motor vehicle, or other unit can do per day, can be measured and a definite standard of work set up. The quantity and quality of work can be readily checked.

The collection of the refuse from the streets presents a different problem, the solution of which is more involved, as to a determination of standards of work and the quantity and quality of work.

Refuse Accumulates Through 24 Hours.

It will be necessary to make clear the conditions under which the dirt appears on the street before considering the quantity and quality of work.

The street refuse is accumulating through every hour of the twenty-four and varies from a fraction of one cubic foot per 1,000 square yards of street pavement per twenty-four hours, on streets of the lightest traffic, to ten or more cubic feet on streets of the

heaviest traffic. The proportion of the dirt appearing at night, or say from 5 p. m. to 7 a. m., is naturally light, varying from nothing to a maximum of 20 per cent of the 24 hour output.

Character and Distribution of Refuse Vary From Day to Day.

These quantities and likewise their character and distribution vary from day to day, and even from hour to hour for the same 1,000 square yards of pavement.

Chart No. 1 supplies proof of these claims. This chart is made from the records of a route by route measurement by volume and weight of the street refuse collected in the course of the work of the Citizens' Street Cleaning Bureau.

Curve No. 1 represents the daily variations by weight, and Curve No. 2 the daily variations by volume of the quantity of street refuse collected from a rough surface, in this case granite. Curves Nos. 3 and 4 show the same facts for a smooth surface, here an asphalt pavement.

The variation in the character of the refuse from day to day is indicated in the divergence of the weight curve from the volume curve in the case of each of the classes of pavements.

Curve No. 5 sets forth the variation in the quantity and distribution of refuse, by volume, from hour to hour, for one day.

Street Refuse Is in Two Forms.

Refuse appears on the street in two forms: As fragments of various sizes, and as fine dust. For convenience, the former will be referred to hereafter as dirt or refuse, and the latter as dust or residual dust.

If a street is given anything like the daily attention it requires, the dirt appearing on its surface through the day will lie in detached deposits here and there with clean spaces of pavement between them. (Chart IV illustrates this point.) It is not necessary, then, to clean the entire street, but simply to remove the individual deposits of dirt.

Hand Collection Principles Defined.

The demands of a proper removal of this refuse from the street surface require the observance of two principles:

1. That the dirt be picked up at or as near as possible to its point of origin in the street.

It must not be pushed in front of a broom or scraper and smeared over clean spaces of pavement to the curb, or until the accumulation has reached a point where it must be picked up. Less labor is required if it is swept into a shovel or scraper just where it lies. The cleaning operation on each deposit of dirt must be so thorough that no noticeable particles are left behind to dry out and to be pulverized by traffic.

2. That the refuse be collected as near the time of origin as possible.

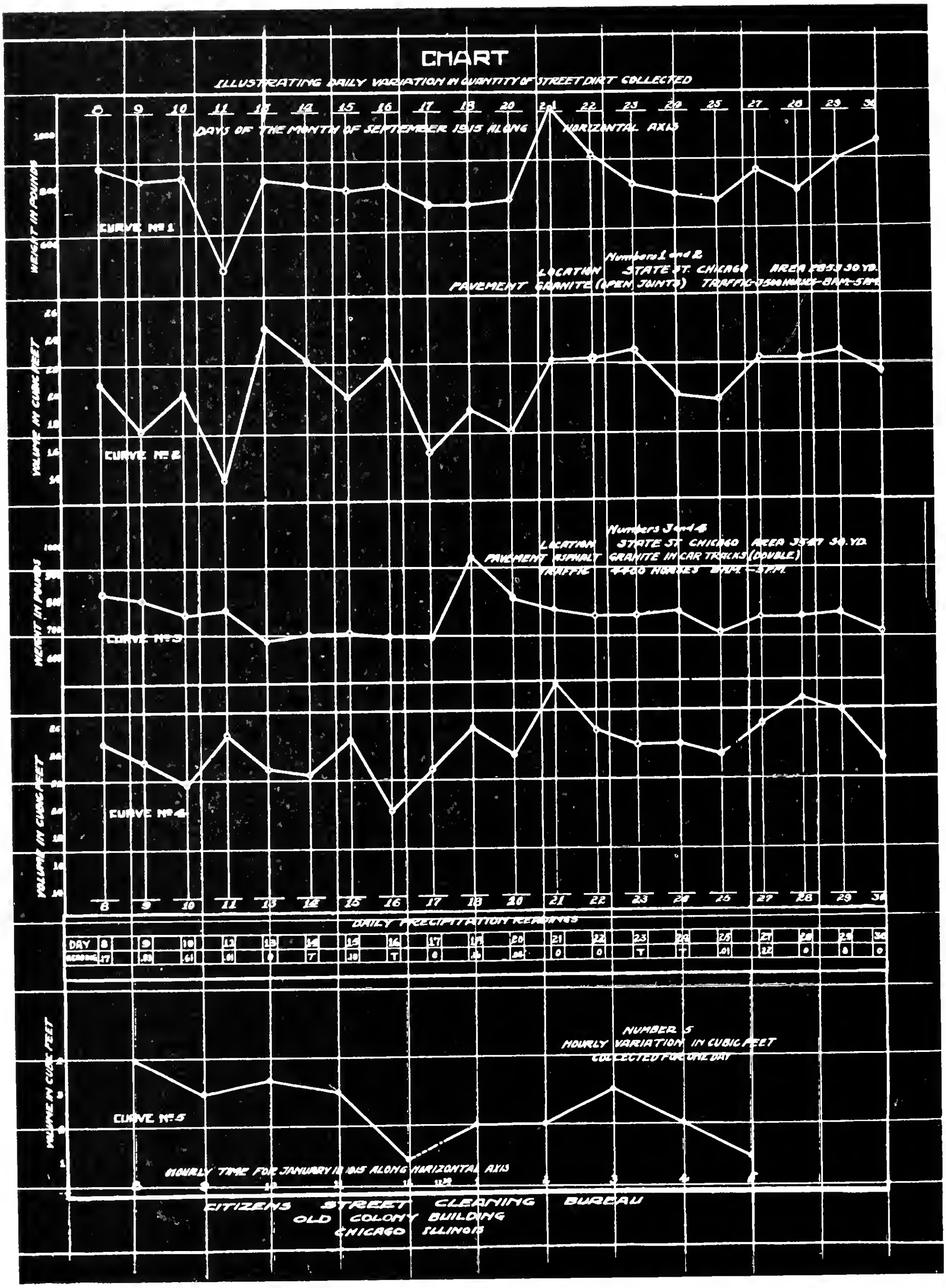


CHART
ILLUSTRATING DAILY VARIATION IN QUANTITY OF STREET DIRT COLLECTED
DAYS OF THE MONTH OF SEPTEMBER 1915 ALONG HORIZONTAL AXIS
WEIGHT IN POUNDS
CURVE No 1
Numbers 1 and 2
LOCATION STATE ST. CHICAGO
VOLUME IN CUBIC FEET
CURVE No 2
Numbers 3 and 4
LOCATION STATE ST. CHICAGO
WEIGHT IN POUNDS
CURVE No 3
VOLUME IN CUBIC FEET
CURVE No 4
DAILY PRECIPITATION READINGS
DAY
NUMBER 5
HOURLY VARIATION IN CUBIC FEET
COLLECTED FOR ONE DAY
VOLUME IN CUBIC FEET
CURVE No 5
HOURLY TIME FOR JANUARY 11 1915 ALONG HORIZONTAL AXIS
CITIZENS STREET CLEANING BUREAU
OLD COLONY BUILDING
CHICAGO ILLINOIS

Chart I

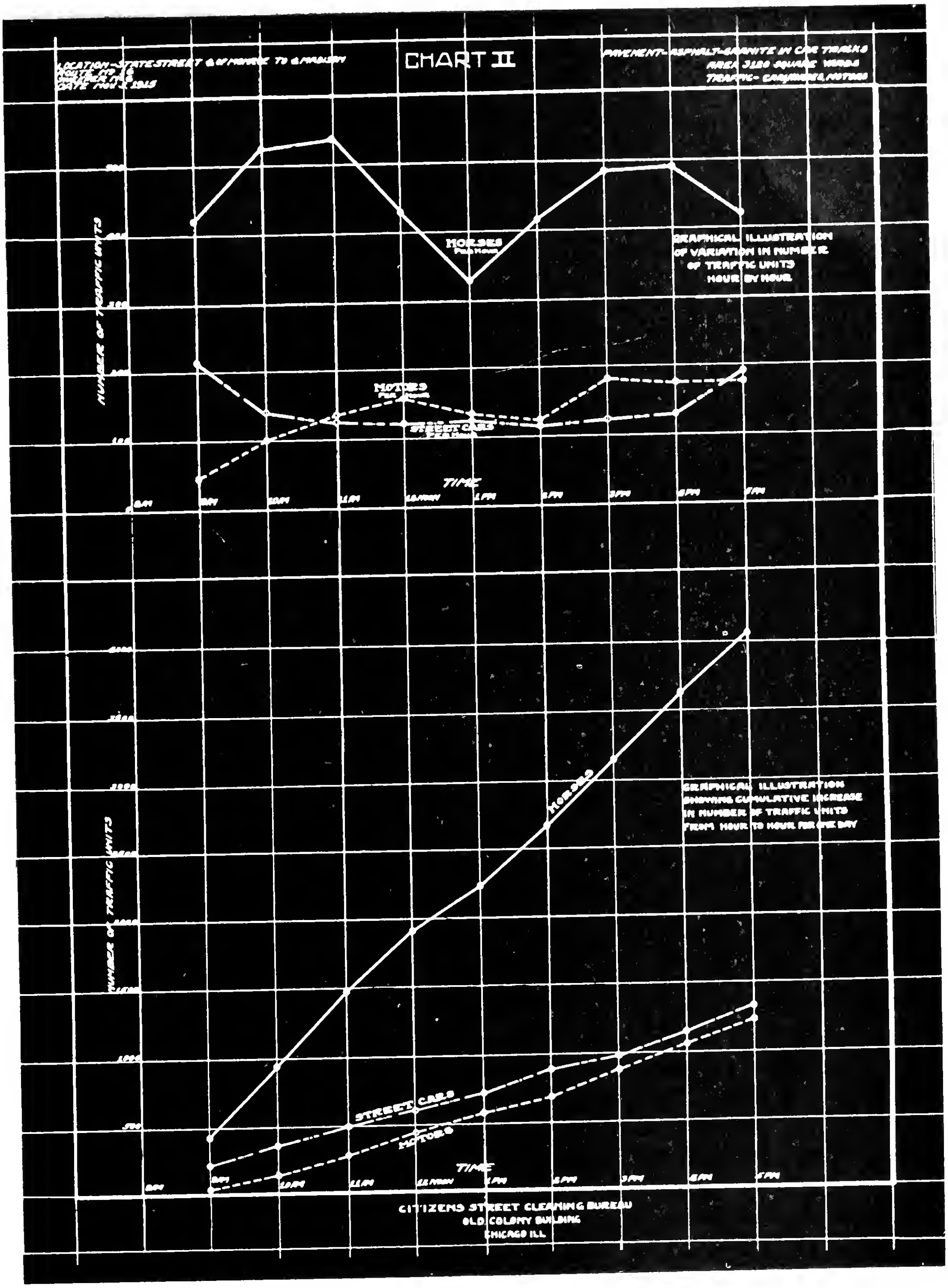


CHART II
HORSES
MOTORS
STREET CARS
TIME
NUMBER OF TRAFFIC UNITS
GRAPHICAL ILLUSTRATION OF VARIATION IN NUMBER OF TRAFFIC UNITS HOUR BY HOUR
GRAPHICAL ILLUSTRATION SHOWING CUMULATIVE INCREASE IN NUMBER OF TRAFFIC UNITS FROM HOUR TO HOUR FOR ONE DAY
CITIZENS STREET CLEANING BUREAU
OLD COLONY BUILDING
CHICAGO ILL.

Chart II

If it is left in the street over a certain limit of time, which will vary with the amount of traffic in the street, the papers and light materials will be scattered by the wind and the heavier dirt will be tracked and spread over the pavement by passing horses and vehicles and embedded in the furrows of open joint pavements or smeared over and pasted to the surface of smooth pavements, all of which adds to the expense of finally removing it. Furthermore, if left too long, the dirt dries out and is ground into dust, which is blown about the street—an annoyance and discomfort to pedestrians and a cause of damage to furnishings in houses and to merchandise exposed for sale inside and outside of markets and stores.

Evils of Dry Sweeping Obviated.

If the dirt is thoroughly collected just where it lies and while it is still moist, no dust will be raised during the operation.

Ever Present Fine Dust Is an Annoyance and Danger.

If the two principles noted above are vigorously and intelligently applied through the day, there will remain on the street, after the day's work is complete, a very fine dust, the quantity of which will depend on the fineness of the broom used in the day's work, and the thoroughness of the cleaning.

This residual dust is the greatest annoyance and nuisance with which the street cleaning forces have to contend, and as a medium for disseminating disease germs it is a menace to health.

It is very difficult to manage, because it is appearing every moment on the street from such sources as the thousands of chimneys, the roofs of buildings, disturbance of street pavements, the fine sand used by the street railway companies, the wear from pavements, sidewalks, wheels, street car rails, etc.—all of which are without the control of the street cleaning officials.

Quantity and Composition of Dust.

I have attempted in Chicago to separate the sources of dust found in the street and to determine the composition and quantity of the dust from each source, but so far the results have not been entirely satisfactory.

The information contained in the following table is interesting as showing the quantity of dust per thousand square yards of surface and its composition and its distribution over the street. The street on which this particular test was made is paved with creosoted wooden block and carries a double car track, which is paved with the same material except for two rows of granite block along the outside of the outer rails. The sidewalks are of cement. The traffic is heavy, as indicated by the accumulation of dirt, 8 cu. ft. per 1,000 sq. yd. per 24 hours.

After collecting the heavy material, the dust from the sidewalk, the roadway (from the car tracks to the curb), and from the car tracks (see Photograph No. 1) was collected with horsehair brooms

and measured separately and samples of each accumulation were submitted to a chemical analysis on a dry basis.

From this data the following table was obtained:

	Sidewalk Lbs. of Dust per 1,000 sq. yd.	Roadway (Curbs to car tracks) Lbs. of Dust per 1,000 sq. yd.	Street Car Right of Way Lbs. of Dust per 1,000 sq. yd.
Silica	0.96	4.70	50.50
Carbon and organic matter	.67	3.00	26.00
Calcium carbonate	.20	.60	6.00
Magnesium carbonate	.02	.30	2.30
Iron	.11	.25	3.00
Undetermined	.04	.15	.20
	2.00	9.00	88.00

Photo 1

Composition of Street Dust.

The silica consists mainly of dirt from the street, sand and gravel from the roofs of buildings, leakage from vehicles, and the find sand used on the car tracks to facilitate the stopping of cars.

The organic matter and carbon consists of refuse paper, manure,

soot, coal and various other volatile matters commonly found in the street.

The carbonate of lime is principally from the limestone, spilled from vehicles conveying building materials, etc., and likewise most of the carbonate of lime found in the dust from the sidewalk is from this source, although some of it is from the wearing down of cement sidewalks by pedestrians.

The iron content exists in the free state and the natural assumption is that most of it comes from the car tracks, although some of it is from the wheels of vehicles and from the shoes of horses and even of pedestrians.

It is interesting to compare the quantity of dust collected from a street carrying car tracks with the quantity collected from a street without car tracks. For purposes of comparison the same classification as to the sidewalk, roadway and car tracks is maintained—a space 16 feet wide through the middle of the street, representing the car tracks, in the case of the street without car tracks.

	Sidewalk Lbs. of Dust per 1,000 sq. yd.	Roadway (Curbs to car tracks) Lbs. of Dust per 1,000 sq. yd.	Street Car Right of Way Lbs. of Dust per 1,000 sq. yd.
Street with car tracks	4.30	6.00	90.00
Street without car tracks	4.00	9.60	2.60

Street Cars Make Dust and Car Tracks Collect It.

The proportionately large quantity of dust collected from the street car tracks is due to (1) the excessive amount of fine sand used on the street car rails, (2) the fact that the grooved rails and other breaks in the continuity of the street surface within the car tracks catch and hold the dirt and dust, (3) the difficulty of cleaning the grooves and the space between the rails in the daytime because of congestion of traffic.

This indicates the necessity for sprinkling, especially the car tracks.

The total quantity of residual dust, if spread evenly over the whole surface of the street, would amount to .15 of an ounce per square foot of street surface, which, of course, would hardly be noticed unless the wind is blowing, or a fast moving motor or street car passes over it.

How Dust Is Removed.

Any system of street cleaning, to be effective, must provide every means possible, such as artificial sprinkling, flushing the streets and even scrubbing them, to combat the evil of fine dust. I find the most effective method and means of routing the dust is to flush the streets at night with a motor driven machine carrying a large tank from which the water is forced out under any desired pressure, up to 70 lbs., by a pump driven from the flywheel of the

motor. Following this operation the sidewalks are flushed and hand squeegeed and finally the gutters are washed and squeegeed to remove any dust from the roadway or sidewalk collected in low places there.

When the weather does not permit of flushing, the noticeable deposits of dust are collected by the men cleaning sidewalks. These men are provided with horsehair brooms, by careful use of which they can collect the dust without causing a nuisance by setting it astir.

Quantity of Work.

The quantity of work—the square yards of street pavement a man can clean daily—will depend not only on the refuse accumulations per thousand square yards per 24 hours, the kind of pavement

Photo 2

—whether rough blocks with open joints, or a continuously smooth surface, condition of pavement—whether in good repair or not, but on the quality of work—whether thorough or not—and on the standard of cleanliness.

The first three factors are definite matters of fact. The remaining two have so far been considered questions of opinion, and have not to my knowledge been defined.

Quality of Work.

The quality of work is a very important consideration, for a street surface not thoroughly cleaned cannot be called clean. If the

horse droppings are carelessly picked up, if the dirt in the crevices and depressions of the pavements is not thoroughly removed; if, in fact, every bit of detachable refuse is not collected, the street has been merely brushed over, and the condition of the pavement falls far short of the aims of proper and sanitary street cleaning.

How Quality of Work Is Measured.

Theoretically, the measure of the quality of work is the quantity of material remaining on the streets after the day's work is complete, less any accumulations after the beginning of the sweeper's last trip over the street. But, as pointed out, there is always on the street at the end of a day's work a certain quantity of fine dust which cannot be collected by the means at the sweeper's disposal. This quantity varies from day to day, which is due to a number of factors not under the control of the sweeper. Therefore, unless there is a very noticeable increase in the residual dust, it is difficult to determine whether or not the sweeper is at fault.

Furthermore, there might be enough undigested portions of hay, oats, and other feed, and bits of paper, together with matches, cigars or cigarette butts, and other noticeable odds and ends, scattered over the street to give it an untidy and unsightly appearance; and yet the total quantity of these would affect but little the amount of residual dust on the street.

Practically, then, this test for quality is not, as a rule, feasible. The practical day to day determination of this element of the work is by the eye of trained and experienced inspectors, who are alert and observant.

What Is a Standard of Cleanliness?

When we say a street is clean, what do we mean? In other words, what is a clean street?

Absolute cleanliness, the ideal condition, means that a street must be continuously free of dirt and dust. This condition can be maintained as far as the heavier fragments of street refuse are concerned, but the cost would be prohibitive. Moreover, it is not necessary, for this dirt is not objectionable, if removed before it dries out, or is scattered and ground into the pavement by traffic. The length of time it can be left on the street will depend upon the amount of the twenty-four hour accumulation per thousand square yards of street surface; or, in other words, on the volume and kind of traffic.

The residual dust from one or the other of many sources, although it may be hardly perceptible, will always lie on the street. Therefore, absolute cleanliness is an impossibility and will continue to be so until the sources of dust beyond the control of the street cleaner are eliminated.

The length of time any refuse other than dust is permitted to remain on the street will determine the standard of cleanliness for that street.

A standard of cleanliness, then, is an arbitrary matter, but it can be made definite for certain conditions of traffic, etc., by specifying the length of time any refuse other than fine dust can remain on the street.

Details of the Intensive Method.

In the conduct of the work of the Citizens' Street Cleaning Bureau, we have developed in following closely the hand collection principles stated heretofore, what may be called the intensive method of street cleaning. The aim of this method is not only to clean a street thoroughly, but to keep it continuously clean throughout the working day.

The street sweepers are assigned a definite length of street, called a route, to care for as in the "patrol" or "block" system of street cleaning. The men are required to clean thoroughly their routes in the first hour of work in the morning, and thereafter to keep the refuse picked up practically as fast as it reaches the pavement. In other words, the work is not allowed to accumulate but is taken care of as it presents itself.

It is apparent that to do this the number of cleanings or trips over the route formerly given under the block system must be greatly increased. This increase is expressed in the statement that the standard of work under the "block" system is based on a certain number of cleanings per day, while the intensive method requires a certain number of cleanings per hour.

The advantage gained in the latter method is that for the same street area cleaned and the same amount of dirt collected the length of time the dirt lies in the street is greatly decreased by reason of the added number of cleanings and therefore a much higher standard of cleanliness is obtained.

The explanation of the ability of the sweeper to increase so greatly the frequency of cleaning, is apparent from a study of the charts which are plotted from records of the location, time of deposit and time of collection of every bit of dirt appearing on a particular route (in this case Route No. 16, which is paved with asphalt, contains 3,133 sq. yd. and produced 24.7 cu. ft., or 737 lbs. of dirt, per 24 hrs.) from 6:45 a. m. to 5:00 p. m. on November 3, 1915.

This route is on State street, the main downtown thoroughfare, and extends from Madison to Monroe.

Chart III is made up of ten diagrams, one for each hour of the day; each successive diagram after 8:00 o'clock a. m. includes all the deposits of dirt for the preceding hours. The chart, therefore, is a visualization of the refuse accumulated on the route at the end of each hour—assuming that the street is not swept nor the dirt disturbed.

Let us say the route is swept once per day, the dirt to be collected is represented in the last diagram of the chart from 4:00 to 5:00 o'clock. The actual condition of the refuse would not be as indicated—it would not be in individual deposits. The sweeper

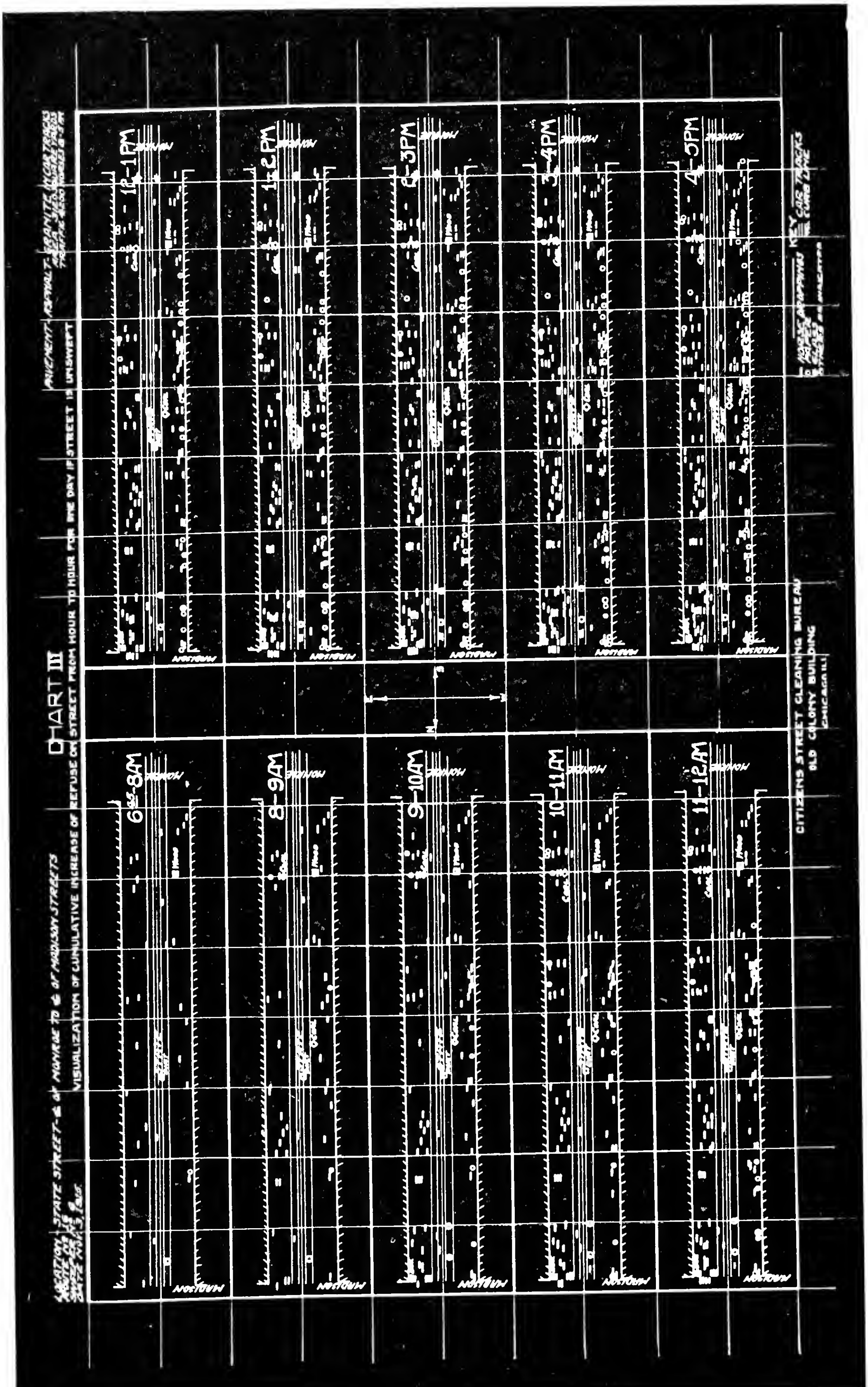


CHART III
VISUALIZATION OF CUMULATIVE INCREASE OF REFUSE ON STREET FROM HOUR TO HOUR FOR ONE DAY IF STREET IS UNSWEPT
6-8AM
8-9AM
9-10AM
10-11AM
11-12AM
12-1PM
1-2PM
2-3PM
3-4PM
4-5PM
MADISON
MONROE
CITIZENS STREET CLEANING BUREAU
OLD COLONY BUILDING
CHICAGO ILL

Chart III

would find it spread over the entire street and adhered to the pavement by the action of hours of heavy traffic and he would be compelled laboriously to sweep with a hand broom every square foot of the surface to clean it thoroughly. The distance walked by the sweeper in the course of the day's work would be at least 4.3 miles, which means that he must sweep a like distance, as this act is continuous through the day.

If we assume that the route is cleared once each hour the accumulation per hour is indicated in Chart IV (we will disregard for the present the figures shown), which represents the refuse actually collected from the route on the date named.

Deposits Are Localized.

The deposits of dirt are shown with clean spaces of pavement between them, and this will be the actual condition, for the dirt will be scattered by traffic but little, when the route is cleaned as frequently as we are assuming it to be.

The sweeper can now use, in addition to his broom, a pan scraper which permits of more rapid and easier work than with a broom alone, and as he can collect each deposit of dirt where it lies without cleaning the entire street a trip over the route is rapidly made. The distance now walked is a minimum of 6.00 miles per day of ten hours. Therefore, the distance walked has increased and the labor of sweeping has been lessened.

Now, if the route is swept seven times in an hour, as shown in Chart V, which is an intensive study of the one to two o'clock diagram from Chart IV, we will see that on trip No. 6 no dirt was collected at all and that the greatest number of pick-ups for the hour was six on trip No. 7. Therefore the sweeper is able to clean the street about as fast as he can walk and the work is accordingly much less laborious than in either of the other instances.

The route in question was swept on the date indicated, November 3, ninety times, the sweeper walking a minimum distance of eight miles in ten hours. That is to say, the sweeper has shifted a considerable part of his daily burden from his arms to his legs. The total physical effort is no greater than in the other instances.

The streets cleaned by the Citizens' Street Cleaning Bureau produce from 5 to 8 cu. ft. of street refuse per 1,000 sq. yd. per 24 hours. On streets of lighter traffic and therefore accumulating less dirt, the street areas or routes allotted per man would naturally be increased. In such case, if the streets are the same width, a sweeper would have a greater length of street to traverse and would accordingly make less trips per day. The length of time elapsing before collection would be increased. In other words, another time standard must be established for the new conditions.

Many Short Periods of No Dirt.

It is interesting to note, from the study of Chart V, that there are periods totaling 21 minutes in the hour from one to two o'clock in which the street was entirely free of dirt. These clean periods average 3½ hours per day for the entire district cleaned.

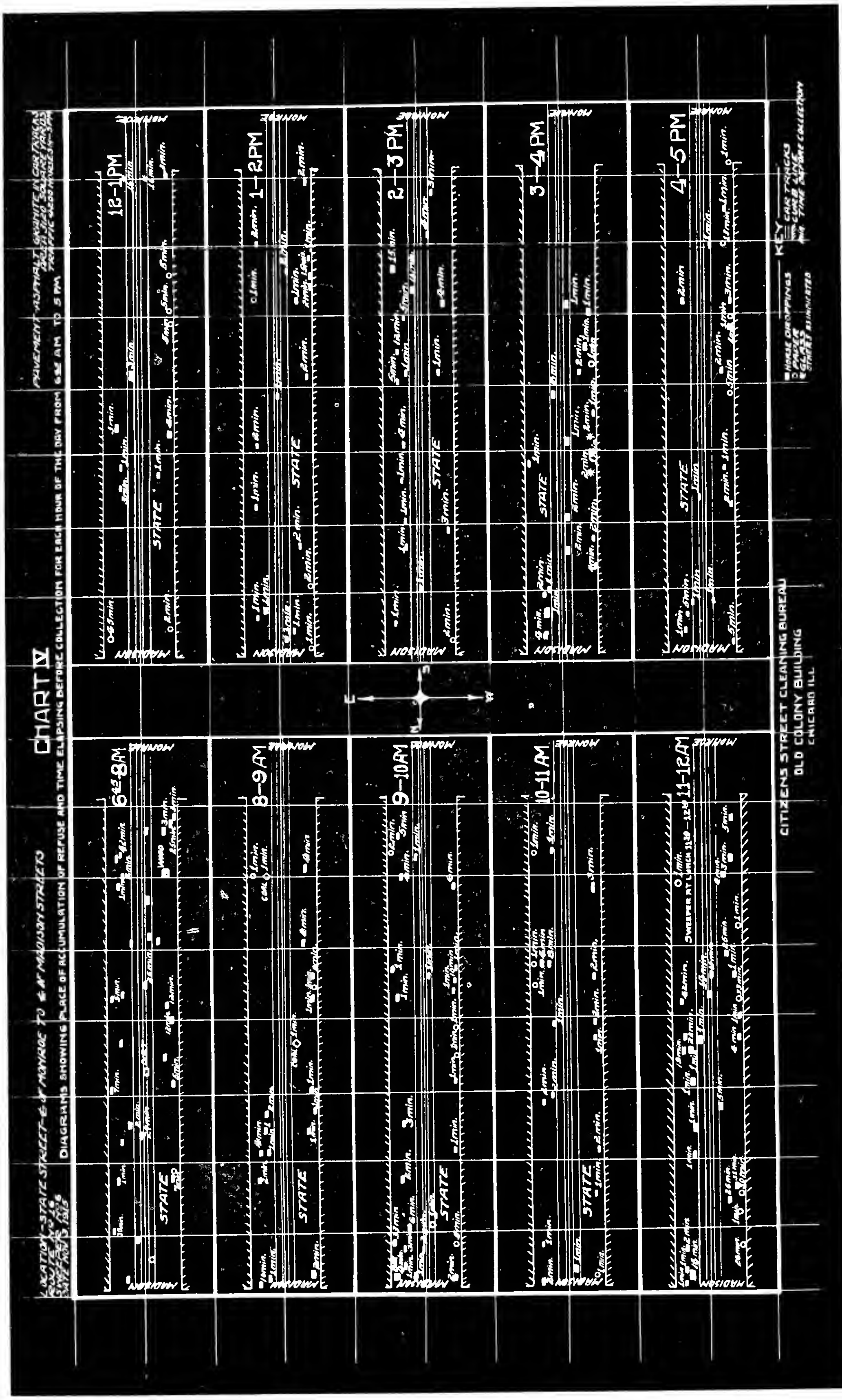


CHART IV
STATE
MADISON
MONROE
CITIZENS STREET CLEANING BUREAU
OLD COLONY BUILDING
CHICAGO ILL.
KEY

Chart IV

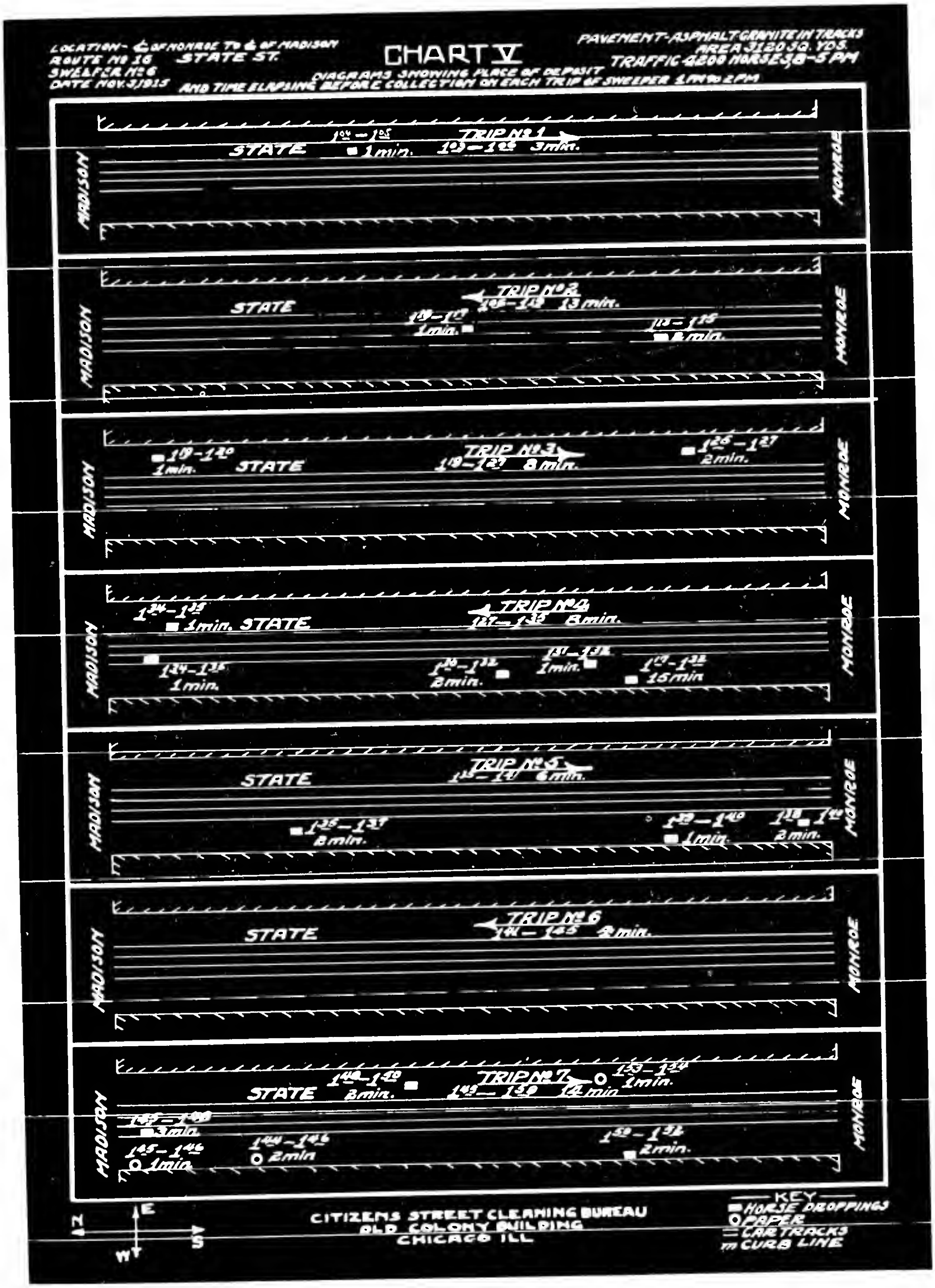

LOCATION- ℄ OF MONROE TO ℄ OF MADISON
ROUTE No 16 STATE ST.
SWEEPER No 6
DATE NOV. 3,1915
CHART V
DIAGRAMS SHOWING PLACE OF DEPOSIT AND TIME ELAPSING BEFORE COLLECTION ON EACH TRIP OF SWEEPER 1PM to 2PM
PAVEMENT-ASPHALT GRANITE IN TRACKS
AREA 3120 SQ. YDS.
TRAFFIC 4200 HORSES 8-5 PM
TRIP No 1
TRIP No 2
TRIP No 3
TRIP No 4
TRIP No 5
TRIP No 6
TRIP No 7
STATE
MADISON
MONROE
CITIZENS STREET CLEANING BUREAU
OLD COLONY BUILDING
CHICAGO ILL
KEY
HORSE DROPPINGS
PAPER
CAR TRACKS
CURB LINE

Chart V

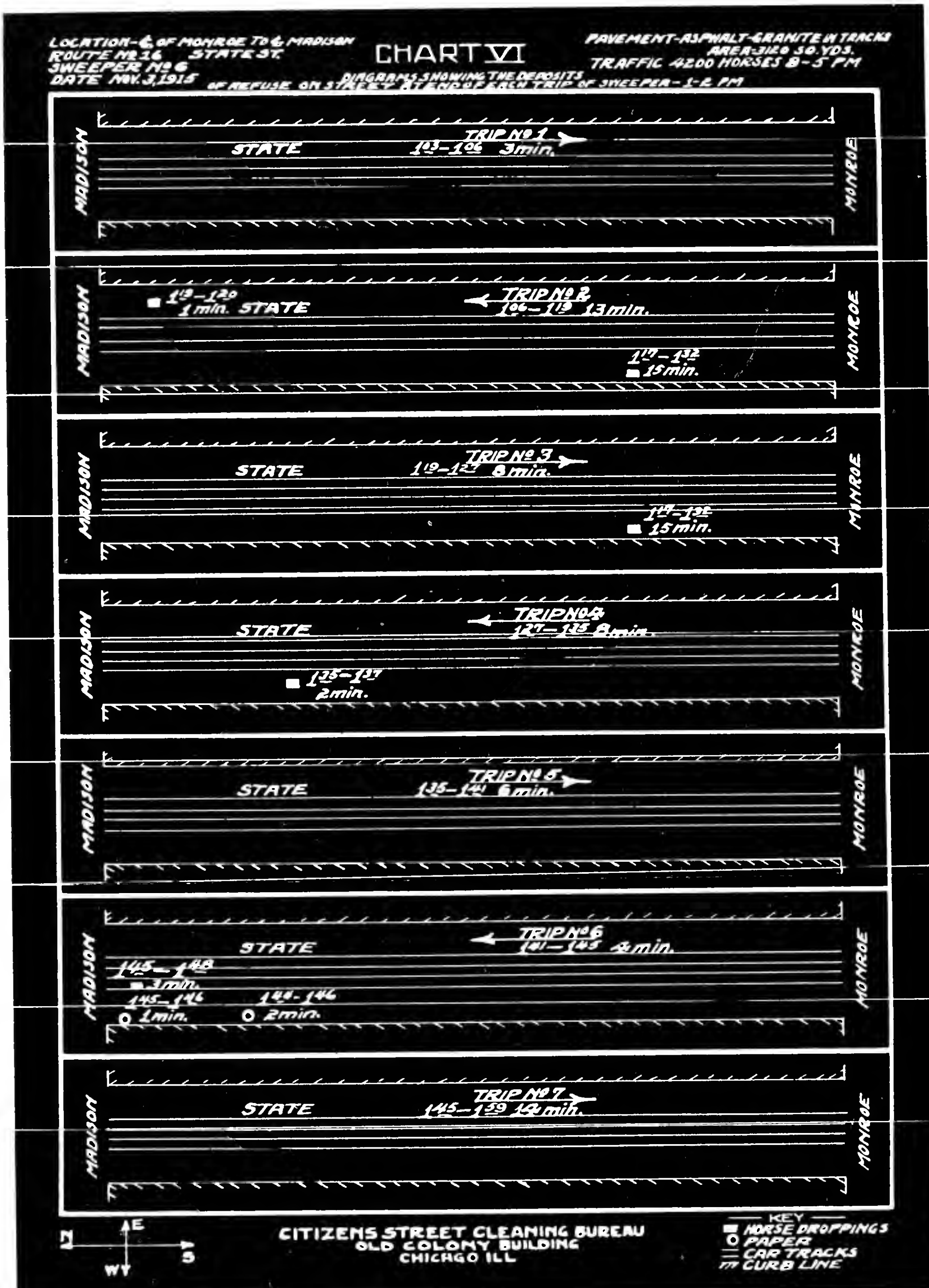

LOCATION-℄ OF MONROE TO ℄ MADISON
ROUTE No 16 STATE ST.
SWEEPER No 6
DATE NOV. 3, 1915
CHART VI
DIAGRAMS SHOWING THE DEPOSITS OF REFUSE ON STREET AT END OF EACH TRIP OF SWEEPER - 1-2 PM
PAVEMENT-ASPHALT-GRANITE IN TRACKS
AREA-3120 SQ. YDS.
TRAFFIC 4200 HORSES 8-5 PM
MADISON
STATE
MONROE
TRIP No 1
3min.
TRIP No 2
13min.
1min.
15min.
TRIP No 3
8min.
15min.
TRIP No 4
8min.
2min.
TRIP No 5
6min.
TRIP No 6
4min.
3min.
1min.
2min.
TRIP No 7
14min.
N
E
W
S
CITIZENS STREET CLEANING BUREAU
OLD COLONY BUILDING
CHICAGO ILL
KEY
HORSE DROPPINGS
PAPER
CAR TRACKS
CURB LINE

Chart VI

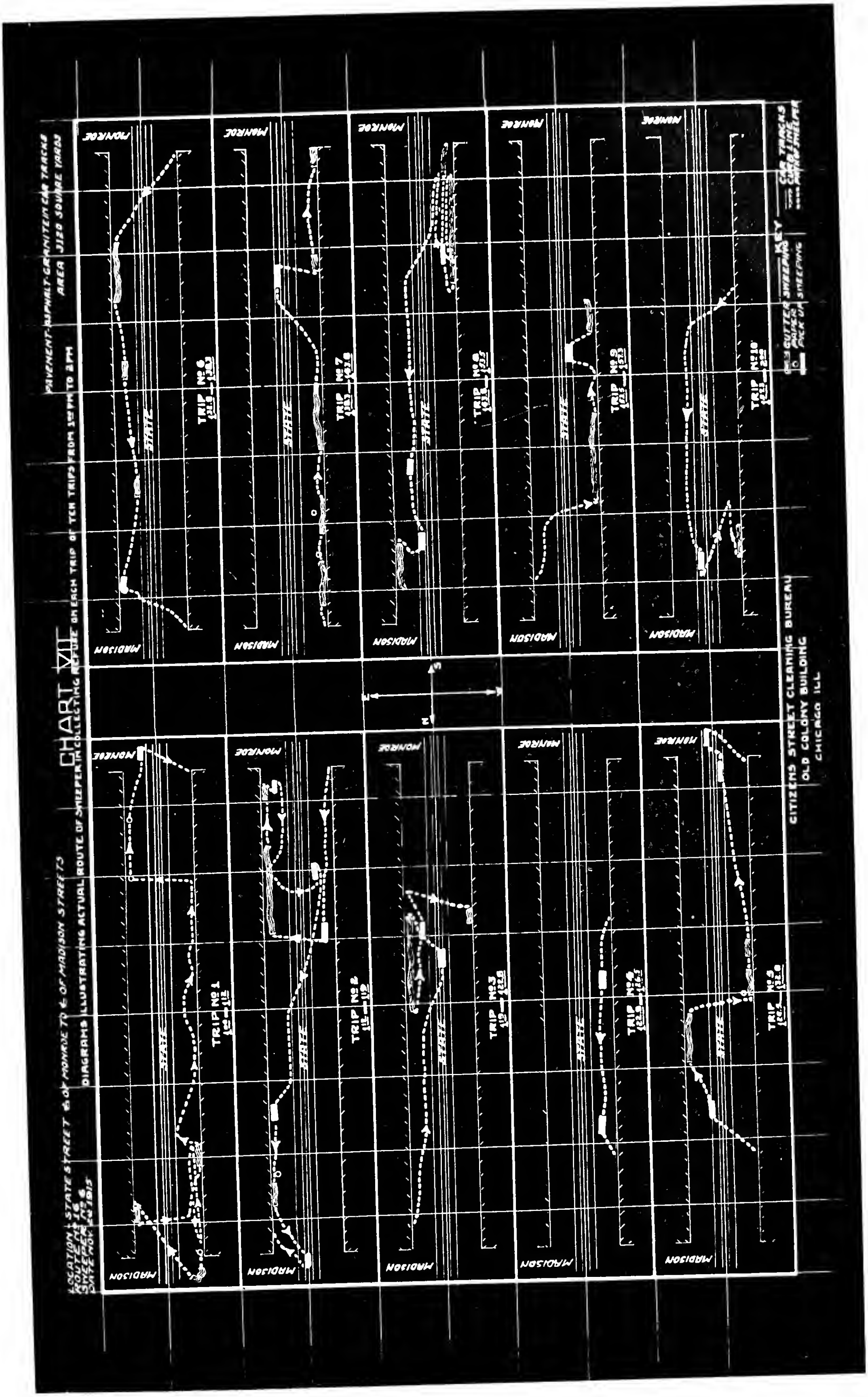


CHART VII
MONROE
MADISON
STATE
KEY
CITIZENS STREET CLEANING BUREAU
OLD COLONY BUILDING
CHICAGO ILL.

Chart VII

Chart VI shows the condition of route 16 at the end of each of the seven trips made over it between one and two o'clock, on November 3. Chart VII shows the actual route traversed by sweeper on each of ten trips from one to two o'clock on November 24.

Now, if we return to Chart IV and consider the time elapsing before collection of the individual deposits of dirt from route 16, we will find, if we exclude the first hour of work and the noon hour, that 48 per cent of the total pick-ups were made in one minute, 72 per cent in two minutes, 94 per cent in six minutes and 97 per cent in ten minutes. Tests made on all the routes cleaned by the Bureau show that under our system of work it is easily possible to collect every deposit of dirt, other than that excepted, within fifteen minutes of its appearance on the streets.

The standard of cleanliness, then, for our streets, under existing heavy traffic conditions, is that the street shall be thoroughly cleaned and that no dirt other than excepted and the fine dust shall lie on the street over a maximum time of fifteen minutes.

While our standard of cleanliness is defined and can be readily checked within close limits, and is checked as illustrated in the above charts from time to time, the day to day determination of this factor is by the eye of the foreman. The standard of cleanliness is so fixed in the minds of the foremen that they can tell at a glance whether or not a sweeper is abreast of his work.

Cost of Maintaining Standard Defined.

The standard of cleanliness here defined is maintained in but few cities anywhere, so naturally the question may arise as to the cost of maintaining it.

The variation in wages paid labor, hours worked, cartage costs, etc., in different cities, would take the meaning out of the figures I would submit. The best way I can answer the question is to make a comparison between what individual men are doing here with what they are doing, say, in New York under similar conditions.

There is no section in New York the exact counterpart of the "loop" in Chicago. The nearest approach to the same traffic conditions is the first district, which is that portion of the Borough of Manhattan south of Canal street. Making allowance for the proportionately greater area of granite in New York, the comparison would stand as follows:

	Area cleaned per man Sq. yd.	Times cleaned per day	Cu. yd. of dirt per 1,000 sq. yd. of pavement per year
New York City......	3,250	5 or 6	56
Citizens' Street Cleaning Bureau	3,000	56	80

The areas cleaned per man do not vary greatly. The times cleaned per day in Chicago are ten times greater than in New York. In other words, the dirt lies on the street in Chicago only

one-tenth the length of time it is allowed to lie in New York. The amount of dirt collected is fifty per cent greater than in New York.

The standards of cleanliness and the quality of work being specified, a block-by-block survey of the quantity of refuse accumulating per twenty-four hours, the kinds of pavement, the condition of pavement and other factors affecting the amount of work a sweeper should do as a daily task, will furnish the information for the uniform allotment of work for every type of conditions.

Frequent and thorough inspections must be depended on to obtain daily the quality of work and to maintain the standard of cleanliness.

In fact, if the work is fairly proportioned to the individual laborer and he is carefully instructed in his duties, the proper cleaning of the streets resolves itself into a matter of a thoroughly instructed and disciplined organization continuous in its management and of adequate and trained inspectors.

A standard of cleanliness, then, for a city, will depend not only on the amount of money appropriated for street cleaning, but on the ability of the head of the street cleaning forces to apportion the work to the individual to the best advantage and to build up an organization that is efficient in supervision, inspection and in thorough cleaning.

DISCUSSION.

Mr. W. J. Galligan: I think Mr. Fox covered the ground very thoroughly. He has told you most of the difficulties that we street cleaners encounter. I think perhaps a word of explanation in regard to the Citizens' Street Cleaning Bureau might be timely. The Citizens' Street Cleaning Bureau was organized ten or twelve years ago at a time when the standard of cleanliness in Chicago was not very high, when the amount of money appropriated for street cleaning purposes was very low. The merchants down town, demanding a higher standard of street cleaning, organized that bureau, paying the expense themselves. Since that time the standard of cleanliness has been steadily advanced. Now, our standard I do not think is any higher than Mr. Fox's or the Citizens' Street Cleaning Bureau, but it is equally as high. I might say that some ten years ago the amount of money appropriated for cleaning the entire city of Chicago was just about the same as what we appropriate now for cleaning the First Ward. So you can see how the appropriations have increased and the standards of cleanliness have also increased in proportion.

Some two or three years ago we made a study of all the pavements in Chicago, and we made time studies, and from those time studies made out our sweeping routes the same as they are downtown. We have continued those studies from year to year, maintaining the high standard of cleanliness resultant therefrom.

A Member: It might be good information for the Society if they knew what proportion the First Ward was to the rest of the city.

Mr. Galligan: We spend about $267,000 now in the First Ward. That is about what we spent in the entire city of Chicago ten or twelve years ago.

The Member: How much does the rest of the city get now?

Mr. Galligan: We spend over a million dollars now, $1,300,000.

J. L. Jacobs: It is rather difficult to speak upon a subject of street cleaning standards and methods after listening to the intensive studies which have been made by Mr. Fox and the results obtained therefrom.

Mr. Fox has given a practical recitation of the problems involved in furnishing satisfactory street cleaning service at a reasonable cost in a section of the city in which business, pedestrian and vehicle traffic is not exceeded in any other similar area in the world. The high standards set and methods used by the Citizens' Street Cleaning Bureau have been looked upon as the standard and goal which the city of Chicago Bureau of Streets has attempted to reach and have been referred to in other cities.

The officials of the Bureau of Streets of the city of Chicago, who are also here tonight, encounter similar and more numerous problems in furnishing effective street cleaning and refuse collection service for all sections of the city outside of the loop district. I am familiar with the details of administration and methods used there, as I had occasion several years ago to make a comprehensive study of the methods used in appropriating funds for these municipal activities and the character and quantity of service rendered.

Although the manner in which the streets are cleaned and refuse collected and disposed of directly affects the health and welfare of every person in the community, the average citizen does not seem to be sufficiently interested or does not appreciate the importance and necessity of good street cleaning and refuse collection service. Only through complete co-operation and interest can these services be performed most effectively and economically. The need for arousing and maintaining such interest and co-operation was brought forward pointedly during the course of the above investigation, and is as urgent today as ever.

The survey above referred to was undertaken by the municipal efficiency division of which I was a member in co-operation with the street cleaning officials and included a study of the service given and methods and equipment used in connection with street cleaning and the collection and disposal of refuse. Based upon the experiences and practices in this and other cities, a comprehensive plan was formulated, whereby these services were scheduled in every section of the city, the work assigned to employes and number of cleanings and collections being based uniformly upon character of pavements, population, districts, traffic conditions, etc. Improvements in administration and equipment were made which resulted in large increases in service. I had occasion to make some comparisons recently of the amount and cost of the street cleaning service in this city and I was agreeably informed that because of the uniform scheduling

of the street cleaning service, an increase in service of approximately 20 per cent has been accomplished since the submission of the report three years ago. This is quite an item when it is considered that approximately $1,000,000 is spent annually for salaries of street cleaners alone.

As result of this investigation some thirty constructive recommendations were made, the adoption of which would have the effect of giving to this city adequate and economical street cleaning and refuse collection services. Among these there were included recommendations that the appropriations and the services given in cleaning of streets and alleys and collection of refuse should be distributed upon definite standards and schedules which take into consideration the conditions controlling the amount and frequency of cleaning, such as density of horse driven vehicles and other traffic, kinds and condition of pavement, character of district and population, location of street, public buildings, parks, etc.

Another important recommendation was that the employment, assignment and tenure of street cleaners should be based on merit and capacity and ability to meet the requirement of a standard day's work. Recommendations were also included for municipal ownership of the collection and hauling equipment and for the provision of a technical planning staff to assist in maintaining uniform service by instructing the men and continue checking the quality of service and the changing conditions in the different sections of the city, so as to plan and distribute these services as the requirements demand.

The figures given by Mr. Fox on the comparative quantities of dirt swept from a given area of pavement in streets with and without street car tracks are most interesting in this regard and bear out the conclusion reached by us as a result of our study. During the course of the investigation the question was raised as to the relative difficulty of cleaning the street car rights of way, and of the money which was being spent by the city for cleaning same for the street railway companies. Annual charges were made by the city against the street railway companies of approximately $200,000 for cleaning all their rights of way in the city streets. With the completion of the study and the installation of scheduled service it became possible for the first time to figure out definitely the actual service given in cleaning of the rights of way and the cost of same to the city. The estimates amounted to approximately $400,000 a year. After considerable discussion, the city was enabled to make a five-year contract with the street car companies, whereby the city would be reimbursed, as I remember, at the rate of $51.50 per month per mile of single track and the city's annual return has, as a result, been increased from less than $200,000 to almost $300,000 per year, or an increase of not less than $100,000 a year for such services. The above is another one of the results of intensive analysis of conditions and definite planning for street cleaning service.

I am going to touch upon one other of the numerous problems which exist in this city and which I think it would be well for the

members of this Society to consider and possibly assist in solving for all time.

As you probably know, this city is the last of the larger cities of this country, and I believe in the world, which still retains the system of having appropriations and expenditures for the street cleaning and refuse collection services apportioned according to political divisions. Ward lines in this city practically correspond to city lines in so far as street cleaning and refuse collection activities are concerned. These thirty-five ward fences stand as obstructions to uniformity of service and hamper most effective and economical results. Street cleaning schedules end with the ward boundaries and the dirt and refuse teams confine their collections within ward boundaries.

The city of Chicago spends approximately $3,000,000 annually for street cleaning and for the collection and hauling of refuse and garbage. About $1,200,000 is spent for street cleaning purposes and the remaining $1,800,000 is spent for refuse and garbage collections and removal. Following the installation and adherence to uniform and definite street cleaning and refuse collection schedules, it became clearly apparent that the division of appropriations and the administration of these municipal activities within political lines results in great annual losses in money and in reduced service. An estimate made last year of the savings which would result if appropriations were made on the basis of the needs of the city without reference to these political divisions showed that at least $300,000 could be saved annually.

The redistricting of the collection service into divisions and districts according to the physical characteristics, population and general tendencies and provisions for long and short hauls, would eliminate great losses of wasted effort and would increase the productive work of teamsters by from 15 to 25 per cent. It does not take a Moses to figure the practicability of this plan, whereby an annual saving of $300,000 can be accomplished, or the service increased by that amount.

Mr. Fox's paper indicates some difficulties which street cleaning officials are called upon to overcome. These are increased when conditions such as the above are thrown in. The advances made in the last few years in street cleaning and refuse collection methods have been considerable, and continued intensive studies, backed up with expert planning and administration, will result in further improvement in these most important municipal activities.

W. W. Deberard, M. W. S. E.: If you drop a piece of paper on State street it will be picked up in 2.7 minutes, on the average. I never tried it, but the figures shown by Mr. Fox indicate more than 50 per cent of all the droppings were picked up within the first minute, so that figure is not so far wrong. This is a wonderful achievement. I do not think there is any other city in the world that has such a system as this is, a system which keeps the streets in such perfect order.

Mr. Fox has been interested in going still farther. One would think after the streets have been covered sixty to ninety times a day that a maximum of efficiency would have been reached. However, there are difficulties with the dust not yet solved and there are kickers in the loop district. They are in evidence every time we have a day when the temperature is very low and it is impossible to sprinkle even the car tracks, from which is obtained the largest amount of fine dust, dust that gets in one's eyes and nose and gives him pink eye, influenza, grip, or just a plain cold. This is no exaggerated health proposition. What are we going to do about it on these windy days? Chicago cannot stand still. It may be ten times as clean as New York is, but we cannot stand still. How are we going to get rid of bacteria that dry up on a windy day, blow around and get in your nose and mine and cause these periodic epidemics of colds? It is not fair to say that they all come from street dirt, but sanitarians tell us street dirt contains these bacteria. If it does, the maximum distribution of it is entirely feasible. How are we going to pick up that very fine dirt which is almost imperceptible and which would not bother anybody so long as the temperature would permit flushing? Various methods have been proposed, but they are all apparently too expensive or impracticable. One which naturally comes to mind is the use of a vacuum cleaner, and if a vacuum cleaner could be made which would be small enough to dodge in and around traffic, get on to the sidewalks and be handled in a reasonable sort of way, that would be ideal; but so far nobody has invented that sort of machine.

Another way which has been proposed and would seem to be worth while trying out, at least, is to use some sort of a dust cleaner, or oiled sawdust such as janitors use to sweep up floors. Sweeping some material that would fix the dust particles and possibly sterilize the germ life from end to end of the street would seem to be an expensive procedure, but in working with it on some of our busiest streets, such as State Street, a solution of the problem along an allied line might be found. Experiments rarely find the correct answer in the solution proposed at the beginning, so it is always worth while to try an apparently prohibitive process financially. If, then, the scheme works, engineering ingenuity can often make it pay.

J. W. Lowell, Jr., ASSOC. W. S. E.: I was very much interested in Mr. Fox's paper and I took especial note of what he said that street cleaning had been perfected almost as much as it could be in the department of street cleaning; that other improvements could be made outside of that department. Now, I think Chicago has done some wonderful work and not only in cleaning up dirt, but also in cleaning up the snow and getting it away. I think Sheridan Road is a beautiful street kept immaculately clean. I think cleaning would be a rough word. You might say manicuring the boulevard. But the problem seems to be a good deal like the old darkey in the South, cleaning up the house. When the master is not looking he kind of sweeps the dirt under the rug. As far as I can see, no matter

how clean you make a floor, if the moldings are dusty and the dirt is hanging from the ceiling, it is going to get dirty pretty quick. It is like sweeping the dirt up and letting it come down again. The other day I rode out on the South Side Elevated, and just after we passed out of the loop, down about Sixteenth or Eighteenth street, the sights that met my eyes were terrible. The streets are filthy. The backs yards are terrible. They could not be in worse condition. They are not only insanitary and foul but they are a menace to the city on account of the fire hazard.

Now, it seems to me that anything that could be done to get this dirt down, or do a little dusting above the streets, would be well worth while. I would like to see something done. I do not know what is done in that line. The loop is kept a little cleaner, I imagine.

Not long ago I saw an article in one of the papers, I think by the fire marshal, which stated that this city had quite a number of thousands of yards of tar and gravel roof which, in itself, was a might big dirt spreader. After the tar got dry that tar and gravel became dust and blew all over the city. He advocated some ordinance to prohibit these tar and gravel roofs. I would like to hear something on that.

Mr. Fox: As I tried to make clear, all those sources which you speak of are without the control of the street cleaning official. He cannot go on private property. He cannot clean the roofs. All he can do is to pick up the dirt on the street, regardless of how it got there. He has no control over the sources whatever and I do not know just how you would control the yards, for instance, that you speak of on the South Side. I do not know whether the Health Department has authority to go in or not. As to the roof proposition, the kind of roof, I do not know what the street cleaning official could do with that.

Mr. Lowell: Only they might work in conjunction with other departments.

Mr. Fox: He tries to work in conjunction with the police where it is necessary to the enforcement of street cleaning ordinances. The building department has control here over permits to occupy the streets for building purposes.

I think that is right, isn't it?

Mr. Miller: The street department.

Mr. Fox: The street department does that. Probably Mr. Miller could give you more light on that.

Mr. A. W. Miller: So far as the back yards, they are under the direct supervision of the Board of Health. They have inspectors going through there and they should report the conditions of those yards. The Health Department should notify the people to clean up. We are asking all the people to co-operate. In fact, we instruct our ward superintendents, our section foremen, as well as the men working on the streets and in the alleys, to have the people co-operate with us and keep their back yards clean. The trouble is this, that we have little co-operation with the people in the city of

Chicago. There is an ordinance that if you are caught littering paper or any other refuse on the street you are subject to arrest, but that is never carried out. If it was, I think some of the people would wake up to the fact that we mean business and it ought to be done. If we could get the co-operation of the people to assist us in keeping things clean, we would not have as much trouble as we have.

As far as roofs are concerned, I know that the large buildings throughout the city are dust and dirt producers, and the only way we can remedy that would be by an ordinance, a building ordinance, and incorporate in that ordinance what kind of a roof they could put on to prevent this dust. That is the only way I can see.

I am instructing the foremen and the ward superintendents, and all of the men working in the wards, to become acquainted with the people in their district and to have them co-operate with us, and we are meeting with some success. Of course, there are a great many people whom you cannot make to understand, and people as a rule are a little against the law; they do not want to be compelled to do things. That is the simple reason of it. They hate to be compelled to do a thing. But if it is coming to that, we shall have to do it.

Fred J. Postel, M. W. S. E.: I would like to get some information from Mr. Fox in regard to his experience with the flusher. We are particularly interested in that, out in Ravenswood, because the Ravenswood Improvement Association operates a flusher and a sprinkler to supplement the work of the City's Street Cleaning Department. Mr. Miller's department kindly co-operated with us to the extent of helping us get a water permit. The Association pays for the operation of the flusher, while the Street Department of the City furnishes us the same number of street sweepers that they have in other districts for the same area. The Association levies an assessment on the property owners to cover the cost of operating the flusher and sprinkler, as well as the snow plows, etc. As a result, we have all of the paved streets flushed once a day, and all of the alleys and unpaved streets sprinkled at least once and sometimes twice a day, during seven months in the year. We find, however, that we have a great deal of trouble keeping our flusher in repair. It is a horse-drawn flusher equipped with a 12 H. P., two-cycle engine direct connected to a centrifugal pump. In most cases, it is true, the fault seems to be due to the attendant not giving it proper attention; but we have probably the same source of help to draw from that Mr. Fox's department has.

I would like to know, first, how much maintenance their flushers require and, second, whether they have very much more trouble with flushers operating on granite paved streets than they have with flushers operating on asphalt streets. Of course, I would expect them to have some more trouble, but I would like to know whether the difference is very pronounced. We found that when we used our flusher on brick pavement our troubles increased. I am not certain whether that was due to the fact that the driver did not want

to cover any more territory than he was previously covering, or whether it was due to the pavement.

Mr. Fox: We had the same trouble. In fact, it cost us as much to keep the engines in repair and furnish gasolene as it now costs to operate a motor driven flusher. The trouble was that the engines were always jostling out of adjustment, and that is probably why you have more difficulty on the brick pavement, because of the greater vibration than on a smooth surface. We had the same experience as you. I do not think the trouble can be charged to the operator, for we changed operators a number of times and could not get one who was able to run the hand flusher economically. So we bought a motor driven flusher. This machine replaced two horse-drawn machines and a hand gang (two men with a hose) on flushing at night and of two sprinkling wagons in the day time, so it is a much cheaper proposition. We operate at a cost of eleven cents a thousand square yards per day. The motor was on the streets from March until October, day and night. It averaged twenty-eight nights and twenty-five days all through that time. We operated it at $15 a day for the two services, day and night. The outfit it replaced was operated at a cost of $28 per day.

Mr. Postel: I would like to ask whether you had it in the repair shop at any time during that period.

Mr. Fox: It worked an average of twenty-eight nights per month, so it could not have been in the shop long. It was in the shop for some minor repairs; that is all.

Mr. Postel: I might add that we attempted to solve our trouble by giving the driver a bonus of $10 a month for every month the flusher was not in the repair shop. The first driver we had, after making this offer, was a rather ambitious driver, and he got the $10 practically every month. Both the driver and the Association were making money that season under that plan; but the next driver we had did not do so well. Either the $10 did not appeal to him or he had bad luck, for, as I recall it, we had some repairs on the flusher every month with the possible exception of one or two months, and it was nearly always engine trouble.

Mr. Fox: We have this arrangement with our chauffeurs: The day driver has complete charge of the machine. He is allowed to name the man who works at night. We give him that privilege. But he is responsible for anything that happens to the machine in the twenty-four hours. In other words, at night when he turns the machine over to the night man he has to examine it to see if anything is wrong. In the morning he examines it again. He knows that he is responsible and he will lose his position if the machine shows neglect. I think this plan of operating the machines has a good deal to do with the results obtained.

Mr. Galligan: I was going to say we put on three power flushers. The first of this season we put on three Locomobile power flushers. We did not adhere to ward lines in their operation but worked them on what we called through routes, for instance, started

at Madison Street and went direct west to the park. We operated them sixteen hours a day, two eight-hour shifts, and covered over twelve miles of street with each flusher in eight hours, and our cost was 4.1 cents per 1,000 square yards. Although the job of flushing was not quite as thorough as we do down in the loop, still they did very good work, especially on street car line streets where there is fine dust in the street car right of way, as Mr. Fox mentioned. It removed the dust entirely and I know it was a source of great comfort to people who had to use the street cars.

Mr. Fox: How many trips did they make, go down one side and back on the other? How many trips?

Mr. Galligan: Just one, that is, up one side and down the other.

Mr. Fox: You see the number of trips on a street would make quite a difference in the cost per thousand yards.

Mr. Galligan: Yes, I know.

Stanley E. Bates, ASSOC. W. S. E.: Speaking of street cleaning by wards, the Bureau of Municipal Research in Milwaukee has made some rather interesting investigations. I think the figures cover two years. In 1914 much of the work was done by wards and no machine was allowed to go outside the boundary of its particular ward, except in special cases. In 1915 the city was redistricted, at least for certain machines. I have not the figures with me, but as I recall it, the new districts were about twice the size of the old,—took in about two wards on the average; and the cost ran about fifty per cent less for that part of the cleaning done with squeegee machines and flushers.

I would like to ask Mr. Fox the amount of money that is available for street cleaning by the Citizens' Street Cleaning Bureau to compare it with the amount the city spends.

Mr. Fox: I did not understand.

President Grant: The amount of money that the Citizens' Street Cleaning Bureau has.

Mr. Fox: How much we expend, you mean? Why, the total cost depends entirely on the amount of snow we have to remove. Outside of snow removal, about sixty-three to sixty-five thousand dollars a year. Snow, for the last ten years, has averaged about $11,000 a year.

Mr. Miller: Does that include $51,000 you get from the city?

Mr. Fox: Yes. The city pays us $51,000 a year and the balance is collected from the property owners. You asked what our operating expenses were, I understood. Was that it?

Mr. Bates: That was it, yes.

Mr. Fox: $51,000 of that is contributed by the city under a contract.

Mr. Bates: What machine other than the flushers does the bureau operate?

Mr. Fox: None at all, the work is done by hand otherwise.

John W. Mabbs, M. W. S. E.: The point has been mentioned this evening of the difficulty of making the illiterate class keep their

properties and surroundings clean and the objections which they offer to any regulations forcing them to do it.

When I was in Panama, nearly four years ago, one of the things that made the greatest impression upon me was the cleanliness of the city of Panama. The conditions of the streets, vacant lots and even the interior of the buildings were most surprising to me. To find a population, which was noted for its shiftlessness and dirt, much cleaner than the same class of people in our own city, was indeed surprising.

The streets are kept immaculately clean and you see nothing in the line of refuse or garbage or anything of this kind around any of the buildings, even in the poorer sections of the city. I asked some of the Spaniards how the place was kept so clean and they informed me that any violation of a street code of rules resulted in the offender being locked up, regardless of his standing or what influence he could command. There seemed to be very little police supervision and with the illiterate class that formed the larger part of the population, it was only a realization that nothing could save them from punishment that kept the city in the condition that I saw it.

It seems to me that if this city would enforce its laws and ordinances strictly, that there would be no trouble in making an ideally clean city. If the people of Chicago realized as the people of Panama do, that its ordinances had to be complied with, we would soon realize the city beautiful.

W. E. Williams, M. W. S. E.: The difference in the quantity of material collected on the street car track as compared to where the tracks are absent, I think was not explained. The point appeared that they drop a lot of sand on the track for traction purposes. Is there any other reason why there should be more dirt on the street car tracks?

Mr. Fox: I think you misunderstood. It was not dirt; I explained that the dirt, the heavy dirt, was picked up first before this test was made and that that material which was swept up was fine dust.

Mr. Williams: Oh, yes, that was only the fine dust.

Mr. Fox: The fine dust. The heavy material has all been picked up before.

Mr. Williams: Was there a greater accumulation of heavy material on the street car track portion of the street than there was where the tracks were absent?

Mr. Fox: No. The excess of fine material on the street car tracks is, as I have explained, due to three things. One was the amount of fine sand, excessive amount of fine sand used by the street car company. They use entirely too much. All the sand, of course, that does not stop on the rail is lost. To give you an illustration of how excessive it does become, we swept up a little while ago along ten feet of one rail and got seven pounds of fine sand. There was no dirt with the sand, just as it came out of the sand box. The second

reason is that the grooves in the rails and the breaks in the continuity of the pavement surface between the tracks, catch and hold the dust. The grooves in the rails are deep and carry a good deal of dust and any unevenness in the space between the rails catches and holds the dust. The third thing is that because of the congestion of traffic in the street car tracks it is difficult for a man to keep it clean during the day. It has to be done at night. It might be flushed or swept out.

Mr. Williams: Another point I would like to know about. Fifteen minutes on your schedule takes up all the material that is deposited. Outside of your district I would like to ask the city officials how often are the streets gone over during the day, further, how about automatic pick-up street cleaning machinery? I have been called upon two or three times in the last twenty-five years to investigate the subject of street cleaning machinery that would sweep the streets and pick up the sweepings. The Patent office shows that a vast amount of effort has been expended in that line of development, but I have never seen any of those machines in commercial operation outside of what might be called experimental tests. My conclusion is that the greatest fault with those machines that pick up the dirt is that the machines cannot vote. Many machines that the patent records show might with proper engineering be worked into commercial machines that would go over a street and take up all the material whether it be fine dirt or dust or mud, slush and snow. Some Chicago men engaged me to submit an outline of a design for such a machine, which I did furnish, but they did not receive sufficient encouragement for the use of it to induce them to invest the money to build it. The general plan of this machine provided for the taking up of the dry dust by the vacuum system, and catching the dust with specially designed dust catchers adapted to handle the material found on the street. In combination with the vacuum system there was also provided rotary brushes, scrapers, and mechanical elevating apparatus that would take up all the other materials not taken up by the air currents. The material would be deposited in a box carried by the machine having a capacity of three or four yards or the material could be deposited in a trailer drawn along behind or at the side of the machine. The box in the machine itself was provided with automatic discharging means adapted to discharge the material from the box of the machines upon a dump or into a trailer or another carrier wagon either at the end or alongside when the machine was moving or at rest. The machine would go over the street and do its work as fast as a horse drawn vehicle ordinarily goes. But you cannot clean the street every fifteen minutes this way. It may be done with that type of machine perhaps not oftener than once a day. Certainly it would not meet Mr. Fox's requirements in the loop district unless he kept a number of them running all the time, and they would have the right of way over the vehicles lodged along the side of the streets. But in the outlying districts, if the cleaning is not done oftener than once or twice or perhaps three

or four times a day, such a machine as that may be made practicable. Whether anybody would have the patience, courage and power to get such machines commercially in use, I consider doubtful.

Mr. Miller: The gentleman made the statement that the machines do not vote. I want to ask the gentleman what city in the United States, what municipality, any large municipality, has a machine of that kind. I wish to ask him who is manufacturing that kind of a machine. The large municipalities of this country are looking for that kind of machine. If he will state the man that makes them we will welcome the machine. I will use every effort I have to secure one. But I do not think any municipality will expend money on an experiment. You must show us. You must demonstrate that you have that kind of a machine. I have been to three or four of the large cities in this country investigating machines, and I have yet to find a machine that will do that kind of work, and if the gentleman will mention to me the man who manufactures one I will assist him very gladly to put it on the market.

Mr. Fox: I was going to say that no machine so far built is practicable under our traffic conditions. In no case have I seen one that is as satisfactory as hand cleaning. Such a one may be evolved some day. I know, too, that they do not vote, but at the same time the hand cleaning has always been considered the most effective method of cleaning the streets. To clean a street four times daily, even, is not sufficient, under the modern sanitary requirements, and if it is swept oftener than four times a day the hand cleaning is less expensive. If you are going to clean the streets only once a day the machine is economical; but if you are going to clean them as often as they ought to be cleaned, the hand cleaning is the better of the two methods and it is less expensive.

Mr. Williams: I agree with Mr. Fox entirely. I stated at the start no machine would meet the requirements which Mr. Fox sets out and is doing in the loop district. I qualified my statement by saying that if the street was only to be cleaned once or twice or perhaps three or four times a day, the machine has a field. I am not aware as to what is done at cleaning the streets outside of the Kenwood district in which I live, which is cleaned by the Kenwood Improvement Association. I think that we have an approximation to Mr. Fox's efficiency. Perhaps the dirt is not all up in fifteen minutes, but we do not have as much dirt. Our district is reasonably clean. A machine would not get the same result as our Association gets. But again if the cleaning is done only once or twice a day along a street a machine that will take up dry dust, mud and slush without preliminary sprinkling has a field. The Patent office shows various approximations of such machines, but they do not seem to come out commercially. Many of them fail in the feature that they plan to dump back on the street in a mass the material that they picked up instead of discharging it into a carrier vehicle that would remove it. I applied for a patent on the pick-up machine which I mentioned, but it has not yet been issued. The Patent office ex-

aminer shows that the art has been so well plowed over that there remains as patentable novelty but little that is new. What is new is termed mostly aggregation. In fact, good engineering is needed more than invention to produce a successful pick up machine. A good many years ago when we had but little else than wooden block pavement in Chicago some machines were used here for a short time drawn by horses that picked up the material, but they dumped it again at intervals along the street. To make a similar machine carry the material that is picked up until it had a load for a cart or wagon and then discharge into the cart or the wagon would not be much of a mechanical trick. With horse drawn vehicles and machinery not horses enough can be handled easily to furnish the power required to run the right kind of a machine for taking up the material. With motor driven vehicles the situation is different; all the power needed can be had. In olden days when Carter Harrison the first gave his friend Cooper the job of sweeping the streets with rotary sweepers I used to look over the bone yard of cleaning machines that had been tried and abandoned. The trouble was not always the fault of the machine, oftentimes it was with the men who tried to use them. Cooper said to me that there was no use of my getting up machinery to clean the streets, the men have not the brains to use them. I depend more on my horses than I do the drivers for the brains to run my sweepers. That may have had some truth, then, or rather a low grade of help was used in this work. With motor driven vehicles a better grade of men are necessary and they can operate a more or less complicated machine. As all kinds of power is available in small space with the motors now to be had, vacuum take up, scrapers, rotary brushes and mechanical elevating means together with mechanical discharging means may be made that will meet the requirements; it is only a question of dollars and cents, engineering, courage and patience. Perhaps the first machine of that class might cost $20,000 and the normal machines thereafter cost about $5,000 apiece. This may seem large, but a good truck costs half that. As to the street car situation since the advent of electric traction there has always been available the necessary power to operate successfully an automatic pick-up machine that could be made to pick up dry dust, mud, slush and snow and readily carry it away as they have available all the carrying capacity needed. Instead of the street car company arranging with the city to clean up the dirt on its part, the street car company should be made to carry away its own material at once and not brush its dust and snow over on the curb and sidewalk, to have it taken up by hand labor. Perfectly successful machinery for this work that will pick up all sorts of material and deposit it in a trailer car as the cars move along is only a matter of patient engineering and some expense, and the street car company should be forced to take away their own dirt, and thus they might be induced to develop such machinery, if it cannot be purchased when sought for.

Mr. Bates: I just wanted to say, as a matter of interest, that

the city of Milwaukee within the last week or ten days has purchased two Elgin pick-up sweepers. This machine is a three-wheeled motor affair. I saw one of them make fairly successful demonstrations in New York, at the exhibition of street cleaning appliances about three or four months ago. I would not want to say how successful the machine is, but it has been purchased by some cities and I know Milwaukee has investigated it very thoroughly and seems to think it worth while spending the money to buy two of them. That is one instance anyway. I do not know of any other pick-up sweeper that has yet proven very successful.

Mr. Galligan: I made several journeys to Elgin to look at that Elgin sweeper. It is one of the rotary broom type which throws the dirt on a belt carrying it into a bin holding three cubic yards. It is an ordinary rotary broom sweeper, sweeping as clean as a broom of that type can, but, of course, leaving much fine dust on the pavement and in my opinion is especially adapted for cities of the smaller class.

I say to the gentleman who has just sat down there is, as Mr. Miller says, a big field in this country for the sort of machine he describes.

Mr. Bates refers to the exhibit of street cleaning machinery that was held in New York. I attended the last two held there, and the city officials of New York sent out word broadcast to manufacturers of street cleaning machinery to bring in their wares for exhibition. It was thought that the exhibit would stimulate interest among designers of special machinery to an endeavor to supply cities with a much-hoped-for vacuum cleaning machine, but up to date a successful one has not materialized. I agree with Mr. Fox.

He asked the number of times the streets in Chicago are cleaned. In the downtown district they are cleaned fifty or sixty times every day. In the outlying sections they are cleaned according to their requirements; none of them cleaned less than once a day.

The Kenwood Improvement Association which the gentleman refers to, is one of the few improvement associations that are left in Chicago: Our aim is to put them out of business. There was a time when the standard of street cleaning was not high, as I said before, but as we are raising our standards, the necessity for the improvement associations becomes less. We do not believe in double taxation. Street cleaning is a function which the municipality should perform. People pay their taxes to have it done. We are trying to bring the standard up so high that it will not be necessary to maintain the private improvement associations.

E. N. Layfield, M. W. S. E.: There is a general impression abroad in the country that Chicago is one of the dirtiest of the large cities. I can see that, it being spread out over so much territory, possibly in some parts of it there is a greater accumulation of dirt than would be the case in other large cities; but I would like to ask some of the gentlemen present who are familiar with the facts, as to whether Chicago in the thickly built up portions is

really dirtier than other large cities, for instance, New York or Philadelphia, or any other city of approximately the same size. I do not refer to the amount of cleaning that is done, or the methods or efficiency of the cleaning, but to the conditions making the cleaning necessary. In other words, is there any reason, natural or otherwise, resulting in a greater accumulation of refuse to be removed, than in other cities?

I was very glad to hear Mr. Miller emphasize the point that the average citizen resents having to obey regulations. The point was aptly brought out also by Mr. Mabbs, who cited an example where, under sufficient compulsion, regulations were obeyed. I remember in the very early part of my career, when I entered the service of a railroad company, I was standing on the back of a train and I very complacently and innocently tore up a newspaper and scattered it over the right of way, and I was very severely reprimanded by the road-master who happened to be on the same rear platform and who was responsible for keeping the right of way clean. The lecture that he gave me on not throwing waste paper around stuck all through these years. This may, of course, be a very small part of the refuse that has to be picked up, but considering the tin cans and bottles which Mr. Mabbs refers to, I think that in keeping our city clean, as well as in a great many other things, a great deal of constructive work could be done by endeavoring to teach our citizens to "obey orders" and to help keep the city clean and to keep their waste paper off the streets and alleys.

Some of us are very much inclined to feel in this, as in other things, that regulatory measures were meant for others and that it is not only easier, but even meritorious, to disregard them ourselves, thereby showing our independence and asserting our liberty to do as we please. A little self curbing of this spirit would be beneficial not only in cleanliness, but in many other ways.

F. D. Nash, M. W. S. E.: I would like to inquire of the gentleman from the city if he did not make a mistake when he said that there was no part of the city that was not cleaned once a day. I think he must have meant once a season, or perhaps in some cases, once a month. Is not that right?

Mr. Galligan: I mean during cleaning season, outside of the macadam pavement. I mean, of course, all permanent pavements. What part of the city do you refer to?

Mr. Nash: Well, I live up in Kenmore avenue, and I think we would be in great luck if we had our street cleaned once a month.

Mr. Galligan: I think you ought to get a pavement first.

Mr. Nash: We have a pretty good pavement there. We paid for it, anyhow.

Mr. Galligan: That was paved very late last year, wasn't it?

Mr. Nash: Yes.

Mr. Galligan: You will get the regular service next year. You did not have anything to clean previous to that time.

Mr. Miller: No, they had a very cheap macadam pavement.

Samuel A. Greeley: Mr. President: I think Mr. Fox should be congratulated on giving us the results of such an extensive study. I do not think there is any class of municipal work in which common sense attention to detail brings out such striking results. After all, it is results that count. We are very apt to overlook the fact that by going over details tabulating and charting them, opportunities for substantial improvements are frequently discovered. Mr. Fox's examples are most conclusive. I am sure Mr. Galligan could give us many others from the results of his extensive studies and that all along the line, examples could be multiplied to show the usefulness of just such, you may almost call them simple, but certainly common sense, studies of the results of various methods of work, and the lines of improvement indicated thereby.

One instance that comes to me relates to dumps. The material which Mr. Fox has been describing in his method of street cleaning, must be disposed of in some way. A great deal of it goes to dumps and there is usually a great deal of complaint against dumps for everybody knows that dumps are apt to be very poorly kept up. In many cases, attention to these details has resulted in vastly improved dumps, which have always got to be a part of street cleaning and municipal refuse disposal service. Admirable examples of well kept dumps are found at St. Louis, Mo.

Another perhaps interesting example that has come to my attention just recently, showing the effectiveness of taking the common sense point of view of some of these smaller details, is in connection with garbage disposal by feeding it to pigs. Some of you know that in Massachusetts pretty much all the pigs in the state are raised on garbage. In the city of Worcester with about 160,000 people, practically all the garbage is disposed of in this way. Two years ago the garbage was fed to the pigs by dumping it in big yards and letting the pigs feed over it. It was found that approximately half of the feed was trampled into the ground and was lost to the pigs, with a good deal of odor resulting. A realization of this condition led to the feeding of garbage on wooden platforms where a good deal of the loss and odor were eliminated. A probable result, next season, will be the feeding in special houses, where none of the material will be lost or trampled in the ground.

I think common sense attention to details is most important. Mr. Fox's paper ought not to go out without that particular point of the problem being emphasized. Such a clear cut result is very welcome.

Mr. Fox: I have no figures at hand on the quantity of dirt collected from the various cities. I do not know what the total quantity of dirt collected here is as compared, for instance, to the total quantity in New York.

Mr. Layfield: I did not refer, Mr. Fox, to the question of

keeping clean. I mean are the natural conditions here such as to make a greater quantity of refuse to be removed? I can see that in the outlying districts that might be because of the great expanse of the city and consequent smaller percentage of paved streets than in some other cities.

Mr. Fox: There are many more miles of unpaved streets here than in New York, and, of course, the unpaved areas contribute much dirt.

Mr. Galligan: How about the roofs? It seems to me Chicago produces more dirt on account of the amount of soft coal burned.

Mr. Fox: Yes, we burn soft coal here and they burn hard.

Mr. Galligan: I think investigations show dust can be carried four or five miles. Chicago's low flat surfaces and narrow lanes formed by high buildings, accelerate the velocity of the strong winds usually prevalent in this section, making the dust problem most serious. Reports of studies on this subject, especially by the medical profession, usually condemn in no uncertain terms modern methods of street cleaning, and lay at the door of street cleaning officials much responsibility for the prevalence of many diseases caused and carried to others by dust particles. Our investigations have shown that dust from pavements or raised by actual sweeping of pavements is less than from any other source, hence we feel that the street cleaner has been indicted on many counts of which he is not guilty.

Mr. Fox: In a report made by Mr. Bottom on the amount of dust from chimneys in New York he figures about a thousand tons per square mile per year in New York. It would be much higher here on account of the fact that we burn soft coal.

F. H. Bernhard, ASSOC. W. S. E.: I would like to ask one more question before the close of the meeting. About what is the relative cost of cleaning a boulevard, say like Jackson or Michigan, which has almost exclusively automobile traffic, compared to the average business street down town, with about the same amount of total traffic? Is it much less?

Mr. Fox: A man cleans 3,500 yards of asphalt surface on State street. He could clean 10,000 yards on Jackson boulevard and more on Michigan avenue, because of the fewer number of horses here.

Mr. Bernhard: Does not that point to one solution of the street cleaning difficulty we may come to ultimately, which is the total banishment of the horse from the city?

Mr. Fox: Between the years 1907 and 1911 the number of horses fell off twenty-five per cent in the loop. The amount of dirt collected from the district that we cleaned was reduced by—I have forgotten now what the figures were—fifteen or twenty per cent. The introduction of the motor is, of course, cutting the horse out, but I do not suppose we will know the day when they cut him out entirely.

POWER STATION BUILDINGS

By James N. Hatch, M.W.S.E.

Presented March 6, 1916

In what I shall say in this paper of the design and construction of electric power stations, I will not attempt to follow out in detail the design of the many parts that make up a power station, but will endeavor to present to you some interesting features of the planning of such structures in their broader aspects.

An electric power station as at present understood is generally a central station, where power is generated in large quantities and is distributed to considerable distances. It is concerning such structures that I will speak to you tonight.

The central station idea has grown up with the development of the modern uses of electric energy, and the present central station has been developed mostly within the past twelve or fifteen years. In the early uses of electricity, before long transmission of energy had been developed, the amount of power required from any one power station was small, and therefore the requirements in the way of buildings for housing the generating machinery were very simple. Almost any sort of a frame building was considered good enough and no special design was thought necessary. The coal was unloaded and fired by hand, the ashes removed with wheelbarrows; no condensing water was required, no traveling cranes were used, and any particular arrangements for the handling of electrical energy at high potentials were unknown.

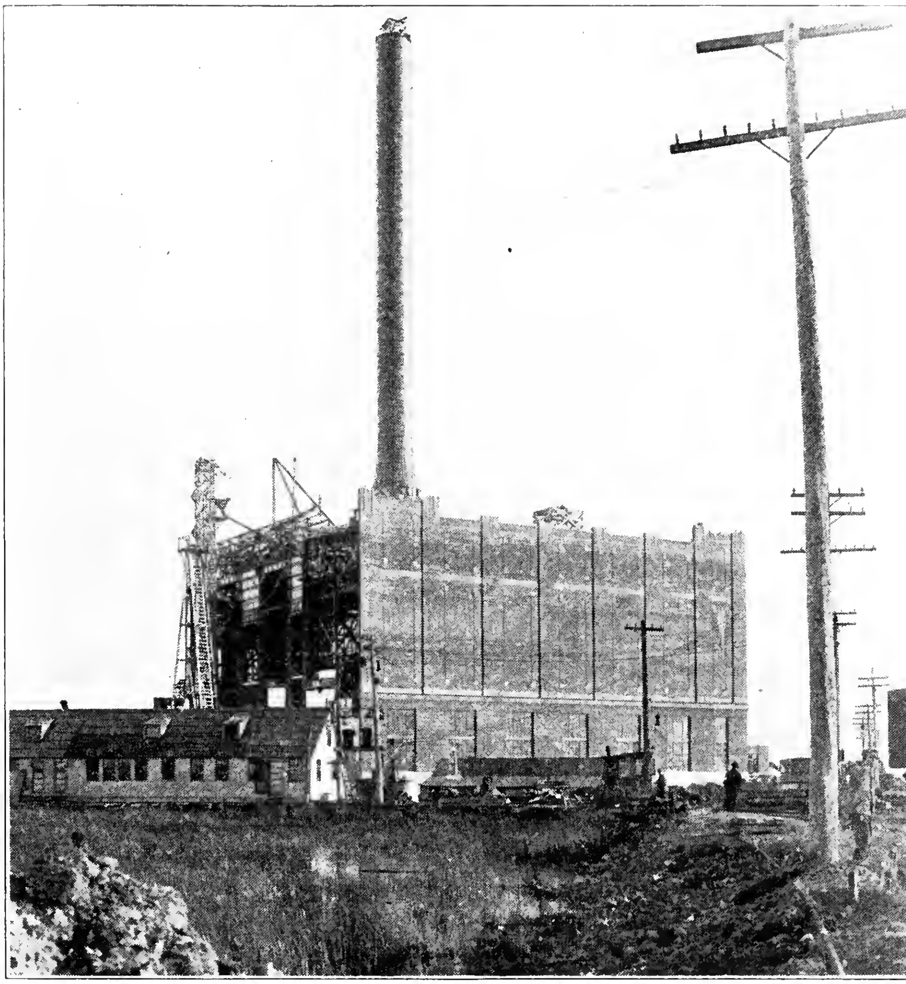
But with the centralization of power in large units the problem of working out a proper design for the buildings and foundations has become a very important branch of engineering.

Most of the modern power stations have fireproof buildings. That is to say, they are built entirely of non-inflammable materials, and as there is nothing inflammable stored in or around a power station, there is nothing that would burn. As a rule, the steel work is not protected with so-called fireproofing, as this is not necessary, for, of course, steel will not burn of itself, and can be destroyed by fire only when the fire plays upon it from some other source.

It is sometimes argued that anything in the way of architectural adornment in a power station building is a waste of money. But the truth of this assumption is to be seriously questioned, and, in fact, in many cases can be absolutely refuted in figures. Thomas Carlyle, in his Sartor Resartus, takes the position that a man is judged, by his fellow men, according to the clothes he wears. That it is the clothes, not the man, that we see, and that therefore we of necessity must judge him by the

kind and quality of his clothes. In a measure, this is true of any business enterprise; it is judged by the outside appearance it displays. And the stability and success of the enterprise and the character and ability of the men behind it are judged, consciously or unconsciously, by the appearance of its physical property.

This is true of power stations in a marked degree, and as



View of Stack of the Conner's Creek Plant of the Detroit Edison Co. at Time of Completion

the building cost is only a very small percentage of the investment in the entire station, the extra amount required to add a few artistic touches to the exterior and interior finish is so small as to be almost insignificant. For instance, suppose the entire station represents an investment of $2,000,000.00, the building portion would probably cost in the neighborhood of $300,000.00. The difference in cost between building this entirely plain and unadorned and building it with a neat, artistic appearance would

probably not involve over $10,000.00 or $15,000.00, which would only represent something like one-half of one per cent.

If the enterprise depends on selling stocks and bonds for its financing, this small investment may pay for itself many times over. For the financial man who examines a property with a view of handling the bonds may be far more impressed by the first appearance he gets of the exterior of the building than by anything else he sees thereafter.

So I would always suggest giving a certain amount of careful planning to the appearance of the building and have it worked out in as good proportions as possible, and built of good-looking, plain material. Not in the attempt to make a power station look like a Carnegie Library or a Memorial building, on the one hand, nor contented with the appearance of a coal shed or an ice house on the other. A power station should look like what it is and have a distinguishing type of its own.

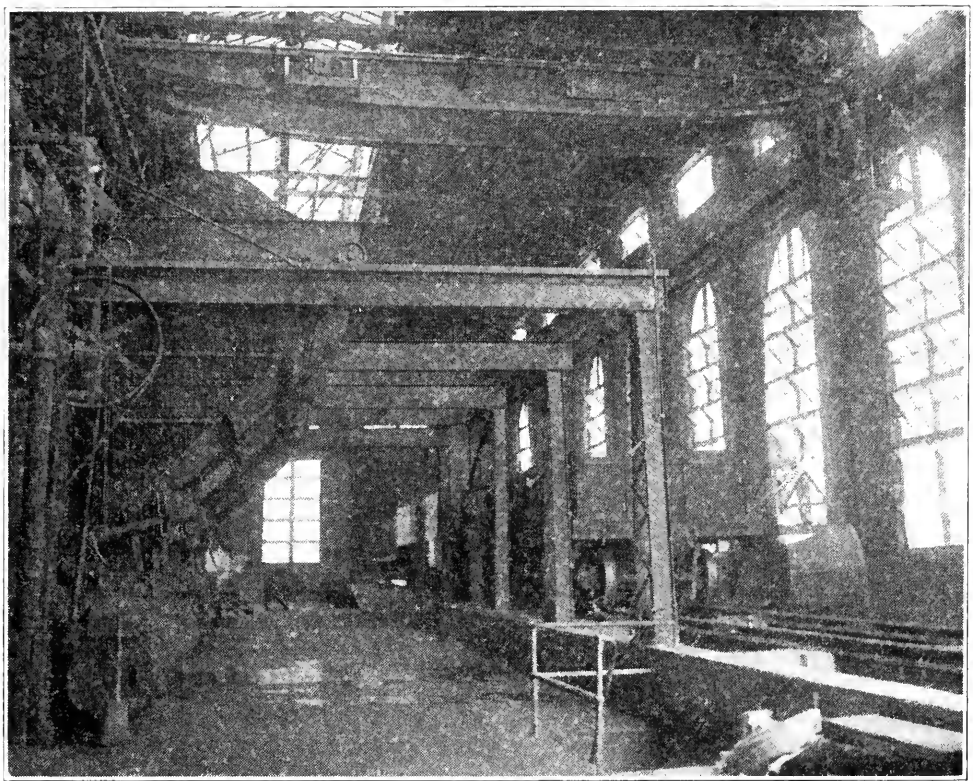
Preliminary Studies

The layout of the machinery is the fundamental determination in planning a power station. But if the machinery layout is made arbitrarily, without any especial reference to the building design, it often becomes very difficult, if not impossible, to design a neat and well-balanced building to enclose the said machinery. For although the artist in reality makes a picture of the clothes instead of the person, he nevertheless strives to bring out the beauty of his subject by the artistic lines and folds of the garments and by a harmonious choice of colors, blending as well as possible with the complexion and expression of the paintee. But there are human frames so ill-shapen and misshapen as to defy the most artistic outline. So it is in planning a power station. In order to make a neat appearing structure, it is necessary that the machinery and apparatus be arranged with some thought of the building which is to enclose them, even though this may not be quite the best arrangement for the machinery itself.

So, for any power station design, it is very desirable that the mechanical, electrical and building engineers work very close together, so that the machinery and the electrical layout can be arranged with some reference to the building features. In order to accomplish this, it is generally necessary to make a number of preliminary studies and then, by a process of elimination and rectification, work out a design that will best serve the ends of all.

As soon as a design is tentatively decided upon which will determine the main features of the building, the work of the real design of the building can be started. The first work is to draw up a skeleton of the building and work up two or three elevations. From the skeleton, a very good idea can be gained

as to where principal loads will be concentrated on the foundations and as to where columns will be located. The elevations will serve to determine the location of windows, doors and other openings. By the time three or four such skeleton drawings have been worked out, some interferences have probably developed that could not have been foreseen and which will require some adjustment in the mechanical or electrical layout. There may be water pipes or steam pipes coming directly through where a column is wanted, smoke flues interfering with the lower chord of roof trusses; coal conveyors coming in the way of doors



Interior of Boiler Room Showing Coal Track and Unloading Crane, Grab Bucket, etc.

or windows, or crane girders getting mixed up with outgoing lines. So when the skeleton has been pretty well developed, a very considerable change is often necessary to make the clothes and the figure conform. A little trimming or padding here and there of the figure and a little careful draping of the clothes will accomplish much, and after one or two more conferences among the engineers representing the different parts of the structure, the actual work on the design of the building can go forward.

Foundation Work

One of the first things to be decided is the kind of foundations that will be required. This is generally one of the most

important things a building engineer has to decide. A large power station is generally located upon some large stream or body of water, so that water for condensing will be readily obtained. This of itself often makes the foundation problem one requiring careful study and planning.

The site for a power station may be on the lake shore, where the high waves and shifting sand make a problem of one nature; or it may be on salt water, where the corrosive conditions are very severe; or it may be on the bank of a river, where the rise and fall of the river between extreme high and extreme low water is 60 or 70 feet; or it may be along the Missouri River, where the quicksands are extremely treacherous; or along the Mississippi River, where the foundation will be on solid rock. Very often the particular site is fixed by some circumstance outside of the province of engineering. The engineer usually has to take things as he finds them, and must design a foundation to meet the requirements and comply with the conditions as they are found to exist.

If the site of the proposed power station is in a city or town, it is often possible to gain considerable knowledge from the investigation of structures that have been built in the vicinity and from an inquiry of the nature and character of the underlying soil. But it often happens that a station is built far away from any other buildings and the engineer in charge must make all preliminary determinations from his own investigations.

In most cases it is necessary to have a number of borings made, and in addition to these borings, it is often advisable to have a few test holes dug down as deep as the earth can be conveniently excavated. These test holes will afford a means of examining the nature of the different strata of earth "in situa."

From this examination, a good idea can be obtained of what loads the earth will safely bear per square foot. The safe bearing power may prove to be somewhat different after the excavation is made, from what it appeared to be from the preliminary examination, but will seldom be different enough to change the design of the building in general.

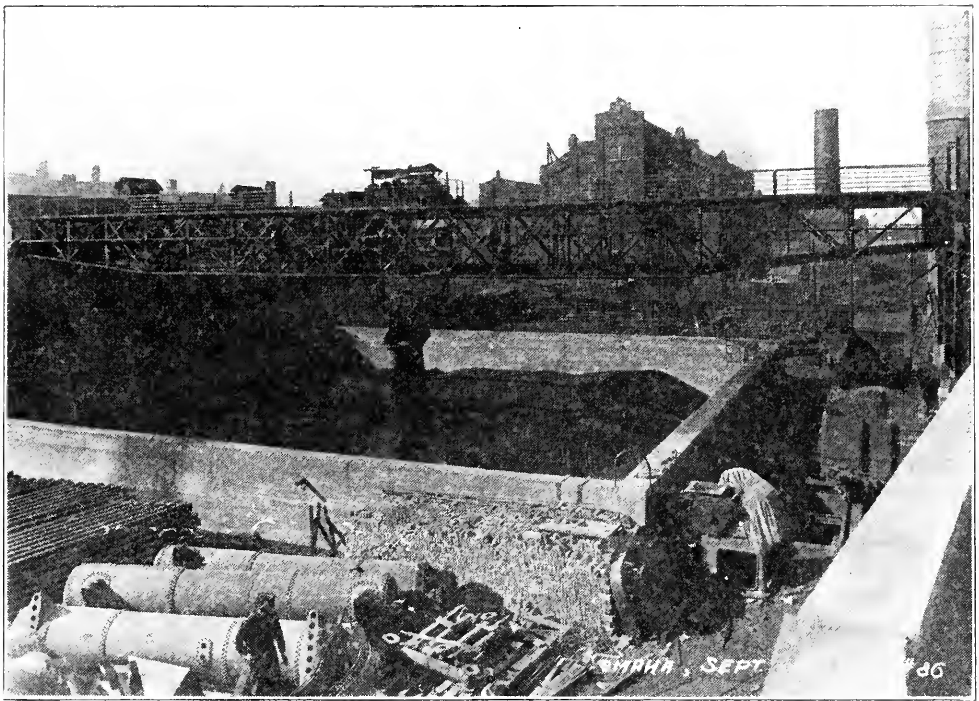
Whether the foundation is simply to rest upon the earth or whether it must have piles or caissons is a matter which must be decided by the building engineer from his investigation of the soil and the surroundings. It is generally necessary to bring a large intake and discharge tunnel into the center of the building. This also complicates the foundation problem.

Of course, the tunnel must be below low water, which may mean that the bottom of the tunnel excavation will be fifty or sixty feet below the main floor level of the station. All this must be carefully taken into consideration when deciding on the style of the building foundations to adopt.

If the underlying material is solid rock and the tunnel can

be driven through solid rock the problem is not likely to be a complicated one, as the building can be safely built over the tunnel without much danger of trouble. But if, as is often the case on the bank of a river, the underlying material is sand and gravel to an indefinite depth the tunnel problem is much more difficult and perplexing. It is very difficult to drive a tunnel through sand and gravel and almost impossible to keep the surface earth from settling more or less over the tunnel.

In spite of the Bible warning against building a house "upon the sand," sand and gravel are about the best materials next to solid rock that can be found upon which to place a foundation for a heavy building. But of course, these materials must be confined and must not be undermined by deeper foundations nearby.



Submerged Coal Storage Pit, Capacity 10,000 Tons

Clay is always a treacherous material on which to place a heavy foundation, especially if it is subject to alternate saturation and extreme dryness. It is very difficult to judge of the load that clay will safely bear, as it seems that almost any clay is subject to some compression, which, although taking place very slowly, may continue for many years and become a significant amount in time.

If, upon an examination of the site, the engineer is convinced that the underlying materials do not have sufficient bearing power to carry the building safely, he must resort to some method of increasing this bearing power sufficiently to make it safe. If it

is found that there is a hard underlying stratum which can be reached by piles, it may be determined to drive piles on which the loads may be carried. If it is found that the materials do not become solid until a depth of eighty or a hundred feet are reached, so that piles cannot be driven to solid materials, it may be desirable to use so-called caissons, made by digging wells five to eight feet in diameter, down to a solid footing and filling these wells with concrete and distributing all loads to these caissons.

But there are cases where the materials do not have sufficient bearing power to carry ordinary footings and do not materially improve in any reasonable depth.

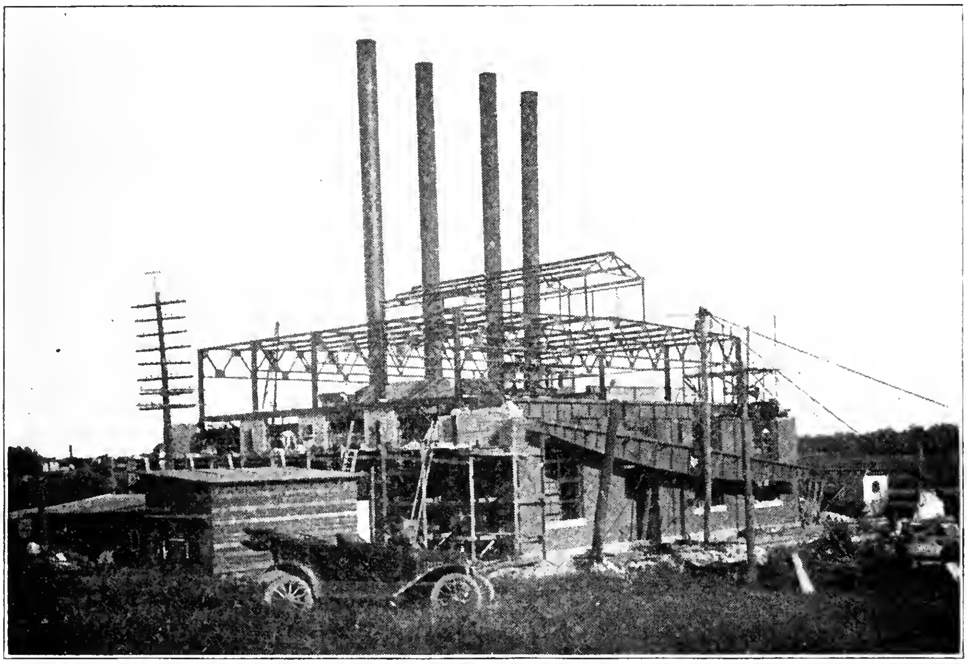
If a heavy building is to be placed on soil of a quicksand nature where piles would not be practicable, some method other than any of those just mentioned must be resorted to. A method which has been used to a considerable extent where ground of this nature was encountered is the placing of the entire structure on a reinforced concrete mat. This mat is generally made five or six feet thick and thoroughly reinforced in both directions, both top and bottom, in the hope that if there is settlement it will be so uniform over the entire building as not to be noticeable. One serious difficulty with this method is to know what is going to happen where the tunnel joins this mat. If the entire mat does settle any considerable amount, it is likely to break away from the tunnel where the two join.

From what has been said, I think it is clear that the determination of what style of foundation is best adapted for any particular location is a problem of itself and must be solved for that particular site and the particular building which is required.

After sufficient preliminary study the engineer will, in fact must, decide the style of foundation which it is best to use, and with this determined, the design of the building can go forward.

As soon as the general arrangement of the machinery has been decided upon and a skeleton plan and cross section of the building has been worked out, and the elevation of the exterior has been tentatively fixed, the detailed location of all walls, piers and columns must be decided upon, so that foundation walls and footing can be designed. Since it is impossible to figure the size of the walls, piers and columns until the loads upon them are known, and furthermore, since it is impossible to know the loads coming upon them before you know their sizes, it would seem that we had suddenly come to a stopping place at the very beginning. And it is just here that it is necessary to lay aside hair-splitting engineering exactness and use a little good judgment backed up with what experience you happen to have at your command. Furthermore, in the design of a modern power station, it is generally impossible to get anything like exact weights of the machinery which is to be installed at

the time the building is being designed. So the engineer in charge, in order to keep things moving and keep a dozen or so men busy pushing the drawings, should be able to decide a large number of these questions off-hand from his past experience on similar structures, or his good judgment of about what will be required. A fairly close estimate can be made of thicknesses of walls and sizes of piers and outside dimensions of columns just from a study of the skeleton of the building; and a fairly close approximation can be made at what the weights of machinery will be, from the weights of similar machinery used elsewhere. The engineer in charge can therefore soon get someone busy figuring the loads from the roof downward that will be transferred to the walls and columns and piers. A careful schedule should be made of these loads, showing at what elevation they



Rebuilding Old Power Station at Holland, Mich.

come on and what each load is from. These should be put on an outline plan of the building and on a cross section, so that they can be readily checked over and so that if, after more data is received, there are changes required, it will be easily seen how the original assumptions will be affected. This loading schedule will be referred to until the building is completed and should be carefully made and checked.

With the loading schedule completed, the design of the foundations can be undertaken. Foundation walls and footings for buildings and machinery are at present made almost universally of concrete. It often happens that the basement floor

will be several feet below the water level at times of high water. In such cases the walls and basement floors must be carefully built and joined, so that they will not leak under the water pressure which may be found under flood water conditions.

I will not attempt to follow through in detail the determination of the sizes of the various members of the structure as this portion of the design is not materially different in a power station from what it is in any other engineering structures, but I will point out some of the problems peculiar to power stations.

Smoke Stacks

In the modern large stations the smoke stack is frequently carried on a steel structure over the boilers. This has a number of advantages. It permits a saving in land and in the size of the building, and permits of one uninterrupted row of boilers. Of course, the argument against this arrangement is its extra cost. There is shown in one of the illustrations the stack of the new Conner's Creek Power Station of the Detroit Edison Company. This stack is three hundred and twenty-five feet above the boiler room floor. The shaft of the stack is about two hundred and forty feet high, and is eighteen feet in diameter. The shell is of steel plates and is lined to the top with brick. The weight of the stack and lining is about 1,300,000 pounds. The lining is carried on the steel shell on shelf angles spaced about fifteen feet apart. This stack structure was connected rigidly to the building structure, and the stack shaft is carried on heavy lattice girders at the roof line of the building. The stack structure itself is about 110 feet above the concrete footings on which it rests.

In figuring a stack for stability, it is first considered unlined, with a wind pressure against the projected diameter of 50 pounds per square foot, reduced to 25 pounds on the smooth circular steel shell. This gives the maximum tension on the windward side of the structure. It is, of course, also figured again with the lining in, and the maximum stresses under either of these conditions are used in each member. A 250 foot stack without the lining will weave six or eight inches at the top under a heavy wind and will weave three or four inches at the top after it is lined.

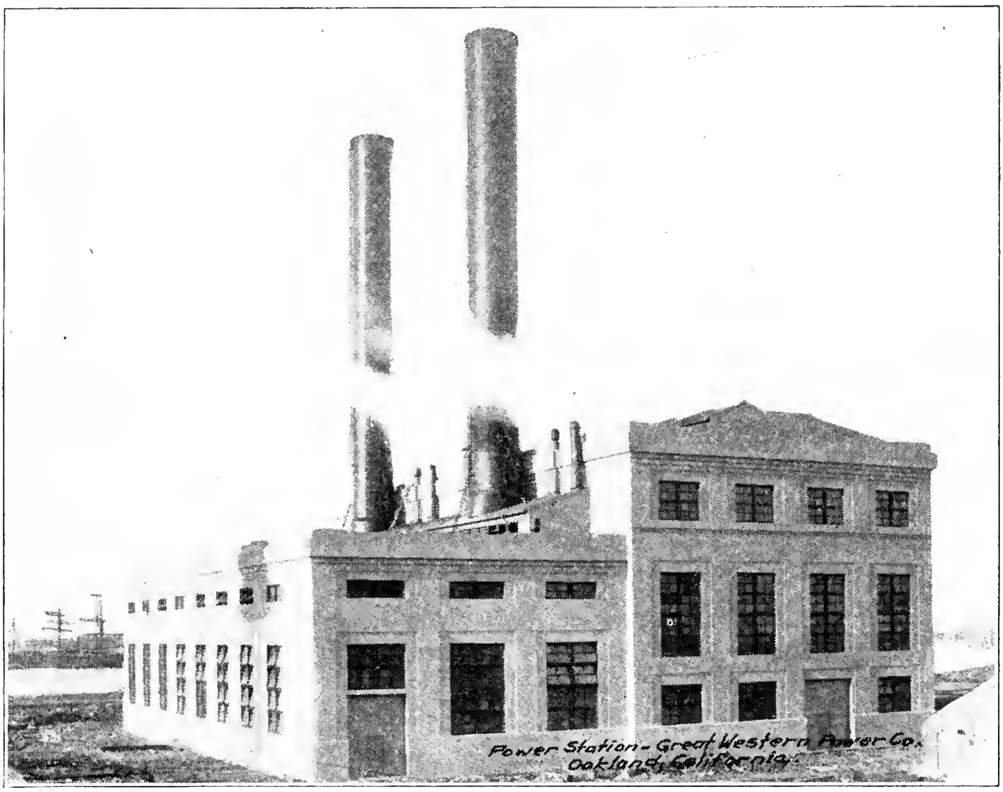
In one of the New York power stations they have carried radial brick chimneys on a steel structure, but I should never recommend doing this. The loads are too great to attempt to carry in such a way, and I believe it would be very difficult to build a brick stack that would not crack with the vibration that would take place under such conditions.

Stacks and chimneys which rest directly on the earth do not involve any special features that need be dwelt upon. Of course, it is necessary to remember that under the maximum

wind conditions the earth pressure at the toe of the foundation on the leeward side of the chimney may become as much as twice the average earth pressure over the entire base with no wind blowing. This must be taken into account when deciding what pressure the underlying earth will be subjected to. Also, of course, care must be taken to insure there being no net uplift under the toe of the foundation of the windward side.

Coal Handling Equipment

Adequate provisions for unloading and distributing the coal is a very important matter for a large power station. In fact,



Power Station, Oakland, Cal.

the choosing of a site for a power station and the whole layout of the plant should be governed to a large extent by the way the coal is to be handled. Or to put it in the reverse order, some definite plan for handling the coal should be one of the first things worked out in laying out a power station. An adequate railway track layout should be planned so that the amount of coal that will be used in the ultimate station can be readily handled. Good switching facilities should be planned, with ample room for storing a reserve supply of coal and adequate trackage for storing a large number of cars to be held a few days at a time. With a station using 3,000 to 4,000 tons of coal per

day, it will be realized that this is a very important problem. For even when the station is using directly from the cars, it will be seen that in order to hold three or four days' supply on hand, it will require the storage of 300 or 400 cars and the returning of 100 empty cars and 8 or 10 cars of ashes each day.

The design of the station and the design of the coal handling appliances must be worked out together. When the switch yard has been decided upon, then the method of unloading the coal into the station and of distributing the coal to the boiler and of collecting the ashes and loading them back into the cars all must be worked in as a part of the building design. The coal must be unloaded and put through the coal crusher and then taken by conveyors to the bunkers over the boiler. There is a great variety of ways in which this can be accomplished, and the particular method best adapted to any given station will depend largely on the conditions that exist there. A large amount of coal is still shipped in ordinary gondola cars without hopper bottoms. So that it is necessary in any large plant to provide means for unloading these cars. This is generally best done by means of a grab bucket operated from some form of crane. With the hopper bottom cars, it is necessary to have a pit in which to unload beneath the track. There must then be planned out a conveyor system for delivering the coal to the bunkers. The illustrations show several different schemes that have been adopted for different conditions. As will be plain, it is necessary to have the coal handling scheme pretty definitely worked out before the building design can be completed, as a large part of the loads on the walls and steel frame come from the coal and the coal handling machinery.

In some modern plants, the coal cars are pushed directly into the boiler room and are either dumped into a pit beneath the track, or, if the cars are not dump bottom cars, are unloaded with the bucket. The coal can be taken either from the cars or from the pit and delivered into the coal bunkers.

The coal bunkers in the Conner's Creek plant of the Detroit Edison Company carry about 500 tons of coal each. These bunkers are made of steel plates and are lined with a thin tile laid in bitumastic cement. A number of eastern power stations have concrete bunkers with steel beam ribs. The main objection to concrete bunkers are their great weight, which makes the steel supporting structure very expensive. Also the concrete becomes pitted and rough, so that the coal does not slide well, and it is difficult to keep them from leaking where wet coal is used.

Unlined steel plate bunkers are the lightest and would be the most satisfactory if it were not for the rusting that is caused by the wet coal. This will gradually eat through the plates and requires the replacing of these plates in ten or twelve years. I

think steel plate bunkers lined with a thin lining are about the best that are known at the present time, and although I do not know of any that have been in use long enough to fully demonstrate the fact, I think they are going to prove quite satisfactory.

Intake Crib and Tunnel

One of the most difficult pieces of construction in connection with a power station is the building of the water intake and

Conner's Creek Power Station, Detroit, Mich.

tunnel to convey the water for condensing purposes from the river or other body of water, to the interior of the Turbine Room. It is probably not generally realized what a large amount of water is required for condensing purposes for a modern station. For instance, a station of 100,000 K. W. capacity will require about 200,000,000 gallons of water per day. To design adequate facilities for the admission and discharge of this amount of water is a very important matter. Especially since the loss of condens-

ing water for any reason is a very serious matter in the operation of a large station. Here is an opportunity for the exercise of a great deal of ingenuity to design an intake and tunnel that will be absolutely reliable and yet make a design that will not be inordinately expensive to install.

As was said before, in order to have a gravity flow into the station, it is necessary to have the tunnel below low water. This, of course, requires that the intake must be at the same depth as the tunnel. As the intake is generally out in the stream, a tight cofferdam must be built, inside which the intake can be constructed and from which the tunnel can be started. This construction is generally a fight with water from beginning to end, especially in sand and gravel soil.

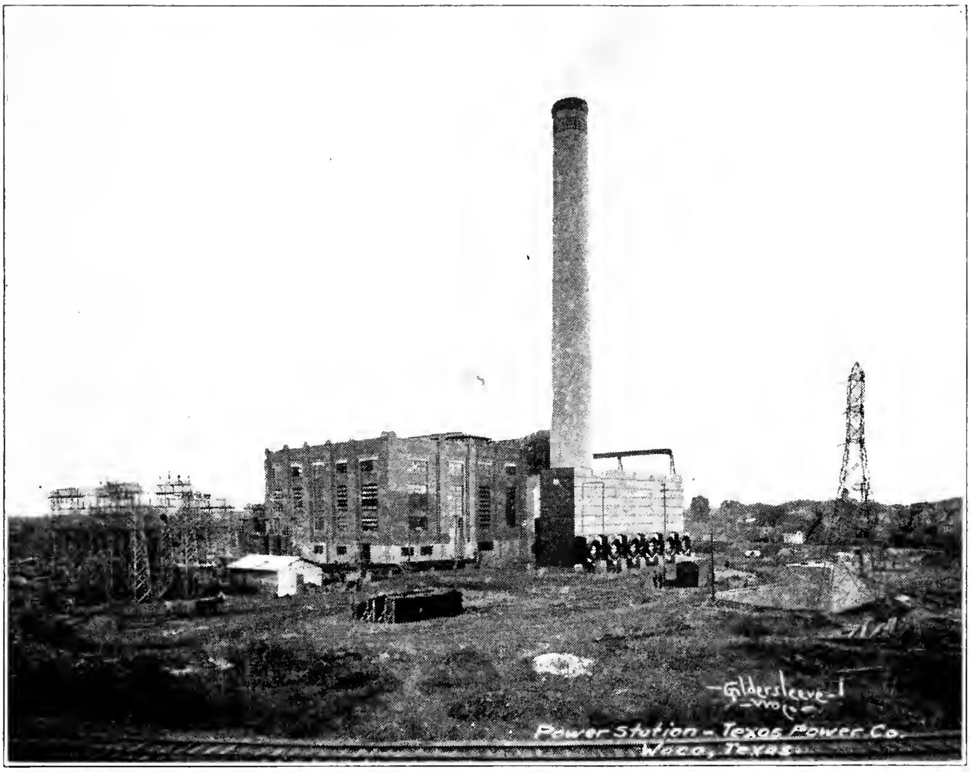
In my experience the open cut method of building a tunnel for the intake and discharged water has proved the most satisfactory, even when the excavation is 50 feet or more deep, except, of course, where solid rock is encountered. In clay soil, the open cut method is not generally a difficult one, if sufficient care is taken in timbering. The pressure from clay banks is sometimes very deceptive and the pressure exerted by these banks, if they once start to move, is sometimes enormous. But if the timbering is carefully done, a very deep excavation can generally be made without any difficulty. In gravel and sand, the open cut method is, in many cases, about the only one that can be used, as it is in many cases next to impossible to drive a tunnel through this sort of material. Compressed air is likely to be of very little use in coarse sand and gravel, for the air will go right through the gravel to the surface and not hold the water back.

In some cases where the tunnel is in sand and gravel, it seemed that it was necessary to use steel piling for the full depth of the cut. Of course, it is a very difficult thing to keep the water out, even with steel piling, for the piling is not water-tight; even if it were, the water will boil up from the bottom of the excavation. But by doing the excavation with a clam shell bucket and not attempting to keep the water out except enough to permit the putting in of the timbering, the excavation can be completed even with 10 or 12 feet of water in the bottom of the excavation. It is generally possible to put the bottom layer of concrete in under water and then to get the water pumped out, so that the remaining concrete can be put in without great difficulty.

While it is not necessary that the tunnel be absolutely water-tight, it should be substantially so, for if there is much of a leak of water, either out of or into the tunnel, there is danger of drawing the sand away from under the tunnel and having a settlement that will break the tunnel.

One of the difficulties to be met with in procuring water

from a river or from the shore of the lake is from the rubbish that is carried with the water. The intake of itself makes a current into the tunnel, and the leaves and rubbish of all kinds is naturally drawn in. A set of removable screens must be provided to prevent the rubbish from going through into the condenser. In several of the later stations, a revolving screen has been installed which has proved very successful. This screen is



Power Station, Waco, Texas

revolved slowly by a motor and the dirt is washed off by a spray of water when the screens pass over the upper sprocket wheel.

Rebuilding an Old Station

An engineer is frequently confronted with the problem of rebuilding an old power station and changing it over into a modern plant. This is generally a more difficult problem to solve in a satisfactory manner than that of designing an entirely new station. For there are limitations and difficulties which are hard to overcome. It is often impossible to rearrange the old machinery as we would like to have it, and it is hardly possible to accomplish just what is desired, but with the exercise of some ingenuity, a fairly good design can generally be worked out.

An illustration shows the rebuilding of the electric power

station at Holland, Michigan, which I have just completed. The old building was very low, and had wood floor and wood roof and was rebuilt as shown by making a new steel frame building about twice the height of the old one of fireproof construction throughout. A traveling crane was installed and everything in the turbine room modernized, including the entire rearrangement of the switchboard and electric distributing system.

All of this rebuilding was done without one moment's disturbance in the operation of the station. One of the first things that we did was to build a little frame switch house outside the building, into which was moved all the lighting and power switchboard panels. This left only four live wires coming out of the building, which we brought out through one of the windows. The generator panels were moved over near the generators, which left the switchboard space free for rebuilding.

While waiting for the steel work to be delivered the footings for the columns were built and everything made ready for the setting of the steel. As soon as the steel was received, the columns were put up, and the trusses erected over the top of the old building. When the steel frame was up, the old roof load was taken off the old wall and the old wall torn down and the new wall built. The turbine room was temporarily bulkheaded off with light lumber to prevent dust from injuring the machinery. When the new wall was up above the old roof the bulkheads were taken out. All of the upper part of the building was completed and the new roof and skylight finished before the old roof was taken down. Even the crane was erected over the old roof. As may be noted from these pictures, the old boiler room has not yet been rebuilt. This will probably be done in a year or two.

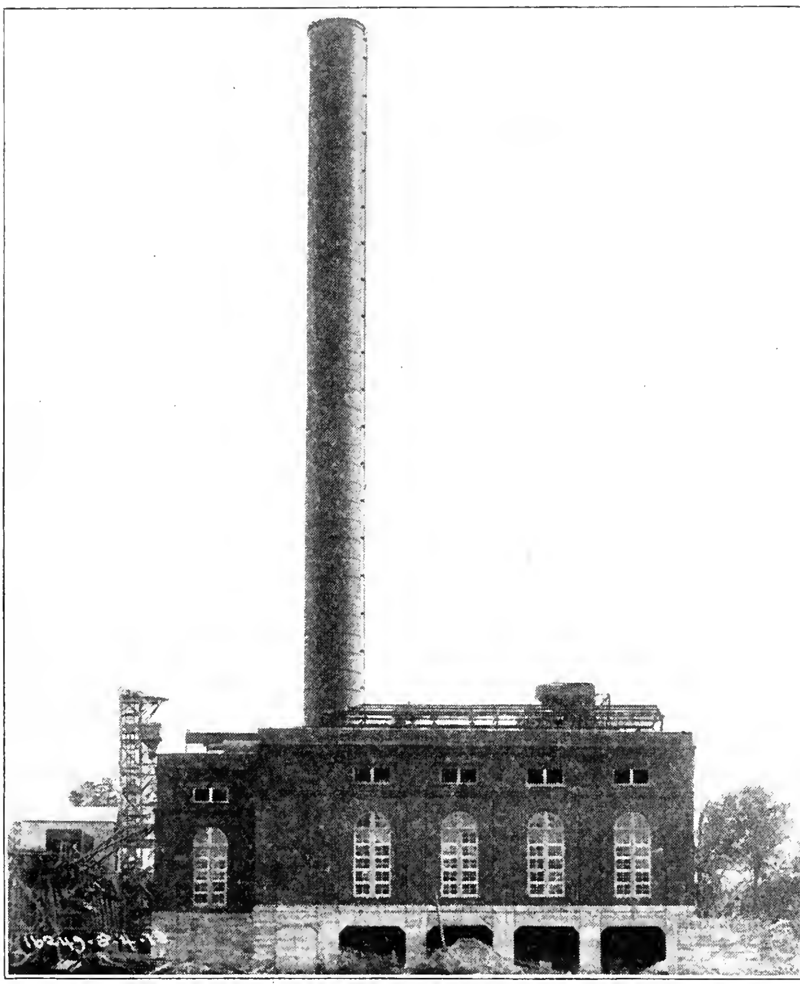
Architectural Features

The design of a power station is an engineering problem, and the architectural features are what the becoming clothes are to the human being. The clothes can be made to help adorn and improve the appearance of the wearer, but they should not hamper the wearer or conflict with his usefulness. In the same way, the purely architectural features of a power station should be given careful study and the whole design of the station should be made with the architectural scheme in view, but the usefulness or economy of the station should not be hampered to any appreciable extent for the purpose of carrying through some preconceived architectural scheme. In fact, this is not necessary, for a very good appearing building can be worked out in harmony with almost any well-planned machinery layout, especially if the two are planned out together.

Some of the illustrations show a few finished power station buildings, and represent an engineer's idea of what a power sta-

tion should look like. I do not contend that they are finished architectural products complying with all the proportions of the classic type of Greek and Roman architecture, but I do believe they are good, sensible-looking structures, well adapted to their uses and purposes, and of good proportion and look very well considering the inexpensive material from which the walls are built.

The building of a power station is generally looked upon as a long drawn out job, and perhaps you have decided that the



Power Station, Gadsden, Ala.

description of how it is done partakes somewhat of the same nature. So although it has seemed to me I have only tripped lightly over the subject, touching only a few of the high spots, I hope I have shown enough to help you understand something of what the problem of constructing a power station really is and have proven that even an engineer may design and carry through a large building enterprise in a successful manner even

before he has been granted a license empowering him with ability to do so by the benign legislature.

DISCUSSION.

J. L. Hecht, M. W. S. E.: Mr. Hatch has been so closely associated with all the power stations that I have had anything to do with in the last ten years that he has very naturally thought of nearly everything that I would think of. One or two points occurred to me, however, while he was talking, that to me seemed important, especially from the point of view of the operating man, and some of these points are quite frequently either overlooked entirely or slighted.

One of them is the provision for future unforeseen requirements. The growth in the electrical industry has been so unexpected in past years that as a general thing, in spite of the fact that an attempt was made to make conservative provision for future requirements, I think that in most cases the provisions made have been inadequate, resulting in difficult problems arising at future times in taking care of the increased demands on the station.

Another point that I think is of importance in designing a power station is to bear in mind the insurance requirements, or perhaps I would better say the things which will enable you to obtain a good insurance rate. It frequently seems to me that the insurance underwriters make requirements, some of which, at least, seem rather absurd; but the fact remains that they have to consider all classes of industries and it is difficult for them, I suppose, to make special requirements in the case of electric power stations; and as a result a few dollars spent in complying with their requirements, even though in the opinion of the engineer it may not result in any marked lessening of the fire hazard, will result in a decided saving in insurance premiums. I think, therefore, it pays to confer with the engineers of the insurance underwriters when designing stations.

Another point which it occurred to me could bear some emphasis is the question of locker and toilet room facilities. Frequently in designing a power station the tendency is to say, "Well, we can put the locker room in place after we get through; we will find some place for it, or we will find quarters for the men"; and then when the time comes to find a place in which to put locker rooms and toilet rooms the quarters which must be taken are unsatisfactory. There should also be provision for rooms in which the floating or transient laborers can place their lunch pails or their lunch, which is more frequently wrapped in old newspapers, and hang their coats and hats. I mean the class of men who shovel coal and do miscellaneous other work. It makes the station unsightly if proper provision is not made for this thing.

Another point I think worth mentioning is proper provision for storerooms and machine shops. This is an item which is frequently left to be taken care of in any way that may be possible at the finish.

In the storeroom question we again usually run afoul of the fire insurance inspectors. A well managed power station will always carry quite a few spare parts, some of which are very inflammable; for instance, spare generator coils, spare transformer coils, etc. These have to be stored in a place that is reasonably dry. You can not stick them away in any corner of the basement that may be available, and if you leave them out where they are not enclosed in a fireproof room the insurance people complain. So I think fireproof rooms should be provided for storage purposes.

Another point that occurred to me while Mr. Hatch was talking was that my observation indicated that power station design is a specialty. We hear of architects who are making a specialty of one type or another of buildings, hospitals or residences, and I believe the power station is more of a specialty, perhaps, than any other type of building. My observation has indicated that where architects inexperienced in power station design have undertaken that work it has generally resulted in both an economic waste and a more or less unsatisfactory design.

The company that I am connected with has taken over a great many power stations and in comparing those and going into the history of how they were designed some of the points which Mr. Hatch mentioned tonight seemed to come home to me.

C. A. Keller, M. W. S. E.: From the views shown by Mr. Hatch, it is apparent that power houses of today have taken on greater proportions in the vertical as compared with the early power houses. I know of a power house in which the lowest point of the building structure, namely, the bottom of the coal crusher pit is approximately 30 feet below datum, the lowest floor level being 24 feet below datum. The highest point of this power house, namely, the top of the stack, is 286 feet above datum and the highest floor level is 92 feet above datum. According to this the difference in elevation between the lowest and the highest floor levels is 116 feet. The principal reason for this difference in elevation is due to the present practice of including all or nearly all of the coal handling equipment within the boiler room and also on account of the more general use of economizers.

In the early power houses the boilers and auxiliaries for same as well as the stacks, were usually supported on foundations more or less independent of the building structure. Now these parts are supported by the steel work of the building. As a consequence, the tonnage of structural steel for the boiler room has been increased from 60% to 90% of the total steel used in the building.

The general arrangement of the modern turbine room is not very much different from that of the old type engine room. The triple expansion engines usually required most of the space, but now the condensing equipment requires the most space. This is because the space efficiency of the condensing equipment has not kept pace with that of the generating unit.

The space required by the boiler room equipment has therefore increased more rapidly than that of the turbine rooms, so that it has been suggested that the power house of the future might have the turbine room in the center with the boiler equipment partially or totally encircling it and the coal reserve surrounding the boiler equipment.

From the European technical literature it has been the tendency over there to reduce the structural steel of the building. They claim this is on account of the greater reliability of the present day coal handling equipment. Coal bunkers of only two hours supply are considered sufficiently adequate. These are very small as compared with the bunkers of power houses in this country, some of which have a capacity of 24 hours supply.

In Europe it is the practice to include the economizer as a part of the boiler by either setting them at the sides or top of the boilers. In this country the economizer is a separate installation, usually mounted above the boilers. In Europe the stacks are short and stubby because they prefer the forced draught system. We, on the contrary, find it desirable to provide tall stacks usually mounted on top of the building structure.

The tendency, therefore, in European power houses is away from the tall building and stacks to a lower and more flat design. By the adoption of the high output boilers, small stacks and the lower building, only one pound of steel is required in building structure for a boiler plant to generate one pound of steam. In this country, it is necessary to provide about four pounds of steel to generate a pound of steam.

Mr. Hecht: Mr. Chairman, there is one point that has not been mentioned I would like to ask Mr. Hatch to say a little about, if he feels prepared to do so, and that is the question of using concrete structures in place of steel structures for power house work.

President Grant: I would like to ask Mr. Hatch if he made any test on bearing power of soils. He mentioned it, but I do not think he said anything about testing it.

James Macdonald, M. W. S. E.: In describing the coal bunkers Mr. Hatch referred to a thin lining but did not describe what that lining was. I would like to ask what he figured on putting in for the protection of the steel.

Oscar E. Strehlow, M. W. S. E.: I would like to ask if the coal is being conveyed to the bunkers by air pressure at any of the power stations, blown into the bunkers.

George Russel Brandon, M. W. S. E.: My experience with power stations has been solely in connection with the cranes used, and it seems to me that the increase in the capacity of the stations is very well reflected in the capacity of cranes. It has not been so very long ago that a ten or twenty ton crane was a large crane in a power plant. Today they are going to 100, 110, 120 and even 150 tons capacity. In one hydraulic power station our company has put in

two 150 ton cranes to handle single pieces weighing 325 tons. The same way with coal handling cranes. The old stations have short span cranes with small buckets and we are increasing them to 120 feet span and even 160 feet.

John T. Walbridge, ASSOC. W. S. E.: My observation has been that in a number of cases it has paid to give considerable attention to the outward appearance of the power house building itself. In certain classes of developments the power plant represents an outlay of probably not more than ten, fifteen, or possibly, twenty per cent. of the total cost of the entire holdings. When the time comes to raise money and issue bonds, the power plant looms up as about the only thing that can be seen and I have observed, where particular attention has been given to improving the appearance of the building itself, that the additional money spent in this way has always paid dividends in helping to finance the improvement. I think that in a good many cases attention to this point is well worth considering.

Norman M. Stineman, ASSOC. W. S. E.: I have a question in regard to chimneys. The usual practice in America is to build very tall chimneys for large power plants. I believe one of the tallest chimneys in this country is something like 400 feet in height, if I remember correctly. What is the reason, if there is any reason, why in this country we go to the expense of building tall chimneys rather than to install forced draft?

Mr. Hatch: The first question was in regard to using concrete structures instead of a steel frame structure in the stations that I have shown here, large central power stations. In the first place, I think any concrete structure that could be designed for a modern power station would be more expensive than a steel structure. I have found even a brick structure, with brick pilasters made strong enough to stand the vibration of the machinery, is more expensive than a steel frame structure. But, aside from that, steel has a great many advantages over masonry construction. One of the reasons is that you can hardly get your building finished until you begin to change it, begin to tear out and provide for putting in things that will take more space or cutting through the walls and taking out a wall where you had one; and if you have reinforced concrete it is quite difficult to make any such changes; it is very difficult to cut through reinforced concrete where the loads are so great. If you cut a hole through the wall you have to provide for such heavy loads, while with a steel frame it is quite easy to take a column out and put a girder across from the other two columns or rearrange it in almost any way.

Another thing is the greater safety of steel in a power station. You never know what is going to happen in a power station, what kind of explosion you are going to have, what tremendous forces are going to be exerted; and while with a steel frame you might damage it so that it would never be any good any more, it is hardly likely that you would throw it down in a pile as you would a con-

crete or masonry structure. I recall in a station of vertical turbines, where, due to an error in throwing an electrical switch, such a jolt was thrown on the generator that the whole top portion of the machine was wrenched loose from the base portion and turned around through about ninety degrees, shearing off eighteen one and one-half inch bolts. That was a pretty good jolt and there is liable to be such jolts all over the stations and I think we are very much safer with a steel frame than with masonry supports.

With regard to bearing power of soil, we often find it necessary to make tests on the bearing power of soil. In one case I had decided what kind of foundations were to be used, where the subsoil was sand for an indefinite depth. When the building was about to be started, the contractor and the owner got afraid of the proposed style of foundation and telegraphed for me to come. When I got there everybody was against me and my proposed foundation. In fact, piles had already been ordered to drive all over the site. Everybody finally agreed with me that if we should make a test on the soil by putting a test load on it and if then there was no significant settlement they would go ahead. I think they agreed if there was not more than a half inch settlement in forty-eight hours they thought it would be all right. We put a test load on about twice what the figured load was, left it on a week or two, and there was no settlement whatever. In fact, it was one-eighth of an inch higher when we got through than when we started, so we decided it was all right.

But in soil where there are no other buildings close by, where you can get absolutely no information as to what the soil will carry, there should be a test load put on and left as long as you possibly can. A week or two, perhaps. I do not think there is any fast rule.

The coal bunker lining I spoke of was one used in the Detroit Edison plant. We coated the inside of the bunkers with a bitumastic cement, which is a very heavy cement, but soft enough when warm so that it will not permit of the coal sliding upon it. It forms a very hard surface, harder than ordinary coal tar. At first it was thought that the cement would be all that was necessary, but as the coal slid down it would keep wearing it away. So on top of the cement they put a thin tile about a half inch thick, laid in this bitumastic cement with the joints filled with cement. As far as I know, it has been very good. The tile holds the cement and the heating of the coal, as far as I know, does not melt it out. The coal slides on it very nicely and it absolutely protects the steel from moisture, which of course is the principal thing.

The question was asked with regard to handling coal by air; by the pneumatic process, I suppose is meant. I do not know whether that has been used anywhere. Of course, you all know that the handling of ashes in that way has been done to a large extent and I have heard that these people who have designed this ash handling equipment have to a small extent handled coal that way, but I do

not know that it has been used in any large power station. If anybody in the audience knows of it I would be glad to learn of it.

The reason that America uses tall natural draft chimneys instead of forced draft, is probably a matter of choice with the particular designers. A great many American engineers do not believe in the added mechanical equipment that is required for forced draft and are fearful of the danger of shutting the station down due to the equipment getting out of commission, for one thing; and of course in a great many cases it is desirable to get the fumes out at as high a level as possible, and a great many engineers feel that the natural draft is a much more secure and much more satisfactory way of getting draft than the forced draft. Of course, as the design of power stations changes and we begin to use economizers more, we will have to come to the forced draft, and in several different kinds of stokers they have to use forced draft. It is possible, and I think probable, that the practice in America will change toward the forced draft in the future.

STEEL BRIDGE DESIGN COMPETITION FOR SENIOR ENGINEERING STUDENTS AT THE UNIVERSITY OF ILLINOIS

In the fall of 1915 a competition in steel bridge design, open to civil engineering students at the University of Illinois, was arranged by Professor Wilbur M. Wilson, and a committee of the Western Society of Engineers, composed of Mr. Albert Reichmann, chairman; Mr. A. F. Robinson, and Dr. J. A. L. Waddell, was appointed by President Jackson of the Western Society of Engineers, as judges of the competition.

The Committee of Award has reached its decision and has made the following awards: E. A. Fock, first prize, one copy of "Design of Steel Bridges," by F. C. Kunz, one year's subscription to the "Engineering News," and one year's subscription to the "Engineering Record"; second prize, H. F. Stocker, one year's subscription to the "Engineering News" and one year's subscription to the "Engineering Record"; third prize, J. C. Stirton, one year's subscription to the "Engineering Record."

The contest was based on the design of a steel bridge with a total length of about 1,100 feet, and the drawings to be made included a general drawing of the entire crossing, showing the piers and the abutments, and the number, type, and length of spans; the stress sheet and the general design drawing for each span; a detailed drawing for the piers and the abutments, and a detailed estimate of the cost.

The prizes were donated by the publishers.

IN MEMORIAM

A. Frederick Zick, M. W. S. E.

Died December 12th, 1916.

Mr. A. Frederick Zick was born in Herzberg, Germany, November 30th, 1878, being the son of Mr. and Mrs. Herman Zick. When he was four years of age the family moved to this country, locating in Watertown, Wisconsin. Here the son attended the grammar and high schools.

His first employment after leaving school was with the Watertown Gas Company. While there employed he commenced a course of night study with the International Correspondence School, which he supplemented after coming to Chicago, with studies in the evening classes of the Young Men's Christian Association. In 1899 he moved to Harvey, Illinois, taking a position with the Austin Manufacturing Company, eventually becoming foreman of the laying out department and acting general foreman of the structural and forging departments. In 1904 he moved to Chicago, and accepted employment with the Jackson and Corbett Company as foreman in their structural steel works. In September, 1906, Mr. Zick became a structural draftsman and checker for A. Bolter's Sons, where he remained employed until February, 1909, when he entered a similar position with the Lassig plant of the American Bridge Company. On February 1st, 1911, Mr. Zick took a position with the North Works of the Illinois Steel Company as checker on structural steel, where he remained until January 1st, 1912, when he returned to the American Bridge Company and remained with that company until May, 1915.

Mr. Zick was married to Miss Edna Holler in Chicago, August 21st, 1901. He was confirmed as a child in the Lutheran church and retained his membership in that church until coming to Chicago. In 1906 he was confirmed in the Episcopal church and continued an active member in that church until the time of his death.

He purchased a residence at Edison Park in 1913, and moved with his family to that suburb. He became much interested in the affairs of the Edison Park Improvement Association and had but recently been elected secretary of that organization.

During the first week of December, 1915, Mr. Zick contracted pneumonia, which grew rapidly worse and resulted in his death December 12th, 1915.

He is survived by his widow and two children, Helen Elizabeth, aged 13, and Edgar Carlton, aged 7 years, to whom we extend our sincere sympathy.

Memoir prepared by J. H. Heald, Jr., and Karl Hellenthal, committee.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

PUBLIC UTILITIES, THEIR COST NEW AND DEPRECIATED. By Hammond V. Hayes. D. Van Nostrand Co., New York. 262 pages. Price, $2.00.

The title to this book of 262 pages is too modest in that it not only covers the field of the title very well, but also very much of the larger field of valuation.

Fourteen chapters cover such subjects as General Consideration of Property Values, Replacement Costs of Physical Property, Value as Going Concern, Good Will, Original Cost, Commercial Value, Worth of Service to Consumer, a rather thorough Consideration of Depreciation and Depreciation Reserves, a chapter on Values for Condemnation or Sale, and a chapter on the Regulation of Utility Undertakings.

The author perhaps unconsciously appears to take the position that the engineer is no more than a compiler of figures for the use of a Court or Commission, whose duty it is to fix value. This is a rather uncomplimentary view of the engineer and one not at all in accord with what is commonly expected of him. The fact that a man is an engineer does not make him a competent witness on value, but assuming that an engineer is by training and experience competent to so testify, there would seem to be no good reason why he should not determine values as accurately as a judge or commission. If all the truth were known it would probably be found that many of the Courts and Commissions have received their first lessons in valuation from the engineer.

In general, the book gives evidence of the very thorough study that the author has given to matters of valuation. Upon subjects where little controversy exists he outlines the established way. Where there are differences of opinion among valuers he states the most reasonable of diverging viewpoints and usually inclines the reader in the right direction.

Among the more noteworthy parts of the book may be mentioned the emphasis placed upon Reproduction under Existing Conditions, his Discussion of the Selection of Prices and his treatment of such matters as Pavements, Overhead and Going Value.

In these days of fierce discussion of valuation matters few engineers will agree with all that the author has to say. It is believed, however, that when the status of valuation principles attains the stability which will probably come in the next ten years, it will be found that Mr. Hayes has been justified in the great majority of his conclusions. C. B. B.

ELEVATORS. By John H. Jallings. American Technical Society, Chicago. 5½ in. by 8½ in., 217 pages.

The author has had a long experience in the design and construction of elevators and treats the subject systematically and with authority from the development of hand-power elevators to the modern type. Many elevators now in service in industrial plants are of old types some of which are likely to remain in service for many years, and it is important for the young engineer to be informed regarding them.

The development of the elevator has kept pace with the other mechanical developments of the age—hand, steam, hydraulic and electric motive power having been developed in succession. Wonderful progress has also been made in control methods, safety devices, improvements in motors. The available literature on the subject is very meager and the book is one that was needed.

The Contents of the book are as follows:—

Part I. Hand Power Elevators.
Belt-power Elevators.
Worm and Gear.

Part II. Steam Elevators.
Hydraulic Elevators.
Part III. Electric Elevators.

ENGINEERING PROBLEMS. By W. M. Wallace. The Technical Publishing Co., London, 1914. 5 in. by 7½ in., 200 pages. Price, 3s. 6d.

This book contains a collection of rules and data on various kinds of engineering work, followed by a great many problems in the form of questions and answers, the answers being worked out in detail. These problems are not in any particular order, but are practical problems for the draftsman or designer, many of which have been submitted to the Practical Engineer (London) by its readers for solution. Others are taken from examination papers of London University, the Board of Trade and other examination papers. From the standpoint of American practice, it is rather unusual for a book to cover such a range of subjects, the problems being those of steam engineering, structural engineering, hydraulic engineering and other branches.

In addition to the regular alphabetical index, there is a very good classified and graduated index which should prove useful. The nature of the problems is indicated by the following taken at random: Balancing Connecting Rods; Wires—Stress Change with Temperature; Continuous Members in Roof Trusses; Plate Girder Design; Leather Belting—Power and Width; Frame Oscillations of an Engine; Ship Valve Pressure Variation; Centrifugal Pump—Theoretical Lift; Venturi Meter Coefficient; Hooke's Joint—Single and Double; Refrigerators with CO_2; Shear Stress Distribution over Section; Moment of Inertia by Experiment.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Meeting No. 930, March 6th, 1916.

The regular March meeting of the Society was called to order at 7:45 p. m. by President Grant, with about 100 members and guests present.

The Secretary reported from the Board of Direction, that at the meeting of the Board held this afternoon, the following applicants for membership were elected to the grades indicated:

Hugh B. Holman, Rochester, Ind. .... Member
Andrew L. Korthals, Chicago .... Student Member
Robert S. Marriett, Chicago .... Student Member
Harold H. Morgan, Chicago .... Member
Harold H. Samuel, Lake Forest, Ill. .... Junior Member
Henry M. Hedges, Chicago .... Member
Albert R. Montague, Dubuque, Iowa .... Associate Member
Joseph H. Whitehead, Chicago .... Student Member
Frank E. Brown, Chicago .... Associate Member
Lorenzo D. Cornish, Cincinnati, Ohio .... Member
Salvatore Lange, Chicago .... Junior Member
Edgar A. Rossiter, Chicago .... Member
Karl J. Drus, Des Moines .... Student Member
John N. Porter, Des Moines .... Student Member
Harold R. Howes, Chicago .... Member
George D. Hardin, Chicago .... Junior Member
Edward J. Noonan, Chicago .... Member
J. Franklin Schach, Whiting, Ind. .... Junior Member
James T. Hanley, Chicago .... Member
Maurice D. Blumberg, Chicago .... Associate Member
Earl M. Nisen, Milwaukee, Wis. .... Member
Louis A. Pettibone, Fond du Lac, Wis. .... Member

The following were transferred to the grades indicated:

Alexander B. Boyer, Chicago .... Associate Member to Member
John C. Penn, Chicago .... Associate Member to Member
Will O. Jacobi, Omaha, Neb. .... Junior Member to Member

Applications for membership were received from the following:

Stanley W. McCassy, Chicago.
George E. Ackerman, Chicago.
Harry M. Conklin, Clear Lake, Iowa.
O. A. Bailey, Chicago.
George D. Griswold, Chicago.
Henry W. Nichols, Chicago.

Mr. H. S. Baker, M. W. S. E., Assistant City Engineer, gave an interesting account of the placing in service of the new Lake Street bridge, and the removal of the old bridge. This was illustrated by some excellent slides and a reel of moving pictures.

Mr. James N. Hatch, M. W. S. E., then read his paper on "Power Station Buildings." The paper brought out a general discussion, which was participated in by Messrs. J. L. Hecht, C. A. Keller, G. R. Brandon, J. T. Walbridge, N. M. Stineman and others.

The meeting adjourned at 10:45 p. m.

Meeting No. 931, March 13th, 1916.

The meeting was called to order at 7:45 p. m. with Chairman Lacher of the Bridge and Structural Section in the chair and about seventy-five members and guests present.

Mr. Isham Randolph, M. W. S. E., made a short address on the life and character of General William Sooy Smith, Past President, W. S. E., who died at Medford, Oregon, March 4th, 1916.

Mr. Malcolm Elliott, Assistant Engineer of the Army, U. S. Corp of Engineers, then read a paper on "Large Modern Lock Gates." Discussion followed by Messrs. W. W. DeBerard, R. M. Wilson, W. S. Lacher, F. G. Vent, C. R. Dart, E. N. Layfield, Murray Blanchard, and Isham Randolph.

The meeting adjourned at 10:30 p. m.

Meeting No. 932, March 20th, 1916.

The meeting was called to order at 7:50 p. m., with about seventy-five members and guests present.

Professor John F. Hayford, M. W. S. E., who had recently returned from Panama, where he went as a member of a committee, sent by the National Academy of Sciences, at the request of President Wilson, to investigate the Panama Canal land slides, gave an informal talk on the subject, illustrated by stereopticon views from photographs taken while the committee was there. While the address was not for publication in detail, it may be said that Professor Hayford's view was conclusive that trouble from the land slides will soon cease and will not recur.

After an interesting discussion of the matter by several of those present, the meeting adjourned at 10:50 p. m.

Meeting No. 933, March 27th, 1916.

This was a joint meeting with the Chicago Section of the American Institute of Electrical Engineers and the Chicago Section of the Electrical Vehicle Association. The meeting was called to order at 7:40 p. m. with Chairman Keller of the Electrical Section, W. S. E., in the chair, and about eighty-five members and guests present. The program consited of four short papers on the general subject of "Electrical Vehicles," these papers being as follows: "Automobile Motor Characteristics," by Mr. F. A. Putt; "Accomplishments of the Electric Passenger Car," by Mr. Gail Reed; "The Electrical Commercial Vehicle," by Mr. W. J. McDowell; "Storage Battery Industrial Trucks and Tractors," by Mr. W. F. Hebard. Discussion followed by Messrs. F. J. Postel, George H. Jones, Street, F. G. Vent, J. A. Cook, Bowman, A. C. King, C. W. Naylor, Stafford Montgomery, J. W. Mabbs, T. Milton, E. N. Layfield, and S. E. Bates.

The meeting adjourned at 10:45 p. m.

Excursion to the Ford Motor Company's Assembling Plant, March 18th, 1916.

On March 18th, about two hundred members of the Society and their friends went by special train to visit the automobile assembly plant of the Ford Motor Company on special invitation of officers of that company.

Special guides were provided and every opportunity extended to us to see and observe the wonderful efficiency of this Company's work.

E. N. LAYFIELD,
Secretary.

Journal of the

Western Society of Engineers

Vol. XXI. APRIL, 1916 No. 4

THE CURRENTS OF LAKE MICHIGAN AND THEIR INFLUENCE ON THE CLIMATE OF THE NEIGHBORING STATES

By Col. C. McD. Townsend,* M. W. S. E.

Presented October 11, 1915.

Congress in the river and harbor act of June 25, 1910, directed the Secretary of War to appoint a Board of Engineers to consider a "Waterway from Lockport, Illinois, by way of the Des Plaines and Illinois rivers to the mouth of said Illinois river," and required a report to be submitted upon a number of novel problems, among others the effect upon the climate of the lake states of the diversion of water from Lake Michigan through the drainage canal into the proposed waterway.

The writer, who was a member of the Board, was appointed a sub-committee of one to investigate this problem, and found that the data available on the subject was slight and unreliable. He therefore instituted a series of observations which he considers of sufficient interest to engineers who have to deal with lake problems to be recorded in the annals of the Western Society of Engineers. The report of the Board is a voluminous document of the House of Representatives, No. 762, 63d Congress, 2nd Session, and the following paper has been derived therefrom.

With the cooperation of the Lighthouse Bureau, simultaneous observations were taken of the direction of the wind, the direction of the lake currents, and the temperature of the air and water, during the months of June, July, August, and September, 1911, at noon at the entrances to the harbors of Chicago, Milwaukee, Grand Haven, and at White Shoal Light in Lake Michigan. The lake was circumnavigated and the direction of the wind and surface temperatures obtained at intervals of ten miles. Off Frankfort the temperature of the lake was determined at different depths to six hundred feet.

The U. S. Engineer Office at Chicago made daily observations of the surface temperature of the Chicago River at Rush Street Bridge and the Detroit office of St. Marys River at Sault Ste. Marie and Sailors' Encampment, and also during portions of July and

*Corps of Engineers, U. S. Army.

August at Mackinac Island, not only noting the direction of the currents, but approximately measuring their velocity.

Finally a continuous series of observations of lake levels by self-recording gauges were taken by the office of the Lake Survey at Chicago, Milwaukee, and Mackinaw, and by the Grand Rapids Engineer Office at Grand Haven, three times a day during the months of June, July, and August.

A similar series of observations were taken in Lake Huron, and partially in Lake Erie. Subsurface temperatures were also observed in the Straits of Mackinac and the Detroit River.

In addition to the observations made by direction of the Board there were available for the investigation a series of observations of surface temperatures by the office of the Lake Survey in 1904, 1905, 1906, 1907, and 1908, and certain observations on lake currents made by the Milwaukee and Grand Rapids offices at various times. On a number of vessels the temperature of the feed water has been recorded during their regular trips around the lakes, but it was found impracticable to utilize the data thus obtained as they were taken at different depths dependent on whether the vessel was loaded or light, and the course of the vessel was not accurately known. A series of observations of lake currents has also been made under the direction of the Weather Bureau in 1892, 1893, and 1894.

The results of many of these observations are given in detail in Appendix C of the report of the Board. They may be summarized as follows:

Winds.

The most noticeable characteristic of the winds is their extreme variability both in force and direction during the period of the observations.

Not only are they constantly changing at every station, but it was very exceptional if they blew from the same direction at the same time at any two stations. There was, however, a decided easterly component to the winds at Milwaukee and Chicago, and a westerly component at Grand Haven and White Shoal Light. Except at Milwaukee there was a greater southerly component of the winds than northerly, which was particularly noticeable at White Shoal Light.

The daily observations of the Weather Bureau at Chicago, Milwaukee, and Grand Haven show a reverse tendency. During the summer months, both at Chicago and Milwaukee there was a greater number of days in which there was a western component to the winds than eastern, while at Grand Haven the eastern and western components were equal, the western predominating during the months of June and July, the eastern during August and September.

These observations are indicative of a lake and land breeze. The observations were taken by the lighthouse keepers at noon when the sun's rays are producing their maximum effect. Soil

having much less capacity to absorb heat than water the air over the land at noon becomes warmer and lighter than the air over the lake and there is a current from the latter to the former to restore the equilibrium. The observations of the Weather Bureau were taken at seven a. m., when the land had had an opportunity to radiate heat, and a reverse current flows.

The prevailing direction of the wind, however, during June, July, and the earlier part of August, was from the southwest, but modified by land and lake breezes. During the month of September it had a more easterly component.

Lake Levels.

The self-registering gauges at Chicago, Milwaukee and Mackinaw, though taken so as to eliminate wave action, shows a continuous oscillation of the water surface, and indicate a constant variation in the location of the points of highest and lowest levels of the lake surface. During the months of June, July, and August the mean of the daily elevations at noon at Mackinaw was 0.14 foot higher than at Chicago, and 0.09 higher at Grand Haven than at Milwaukee. During the month of September the average levels at Mackinac more nearly approximated those at Chicago and during the last ten days of the month those at Chicago averaged about one-tenth of a foot higher than at Mackinaw.

Temperatures.

During the period of the observations the air was warmest at Milwaukee and coldest at White Shoal Light, the average air temperature at Milwaukee being one degree warmer than at Chicago, 3.4° than at Grand Haven, and 10.2° than at White Shoal Light. But it is to be noted that White Shoal Light is at a considerable distance from land, so that its air temperatures are affeced by lake influences whatever the direction of the wind.

The maximum temperatures observed were 96° F. at Milwaukee, July 3, 96° at Chicago, July 5th, 90° at Grand Haven, July 8th, and 75° at White Shoal Light, July 8th.

The surface temperatures of Lake Michigan during January and February are approximately 32° and they gradually rise to a maximum in July and August, which varies from year to year.

During the period of observations the maximum at Chicago was 76°, Milwaukee 72°, Grand Haven 78°, and White Shoal Light 68°.

This maximum is affected:

First. By the latitude of the station. In Lake Michigan the maximum monthly mean during the period of the observations was 68.3° F. at Chicago and 65.9° at White Shoal Light; in Lake Huron, 68.8° at Light Vessel No. 61 off Fort Gratiot at the southern end of the lake and 63.2° at Poe Light Ship at its northern end.

Second. By the depth of water in the vicinity, being cooler as the depth increases. The observations of the Lake Survey give

a maximum monthly mean in Lake Erie of 77.4° at Toledo, 73.4° at Horse Shoe Reef, off Buffalo; in Lake Huron, 75.2° at Charity Island, Saginaw Bay, and 72.5° at the light vessel off Fort Gratiot; in Lake Michigan 69.7° at Eleven Foot Shoal northern end of Green Bay, and 66.6° at Lansing Shoal.

Third. By the direction of the prevailing winds. At Milwaukee the mean surface temperature of the water during the month of July with the prevailing winds from the west, was 64.1°, and at Grand Haven on the opposite side of the lake, 71.8°. In September when the winds had a more easterly component the mean surface temperature of the water at Grand Haven was 57.3° and at Milwaukee, 62.9°.

At any given locality surface temperatures are very variable, variations as great as ten degrees being liable to occur in summer within a few hours by a sudden change in the direction of the winds. This was more clearly shown in the log of the steamer "Hancock," which was employed in circumnavigating the lakes, than in the observations at the different light houses.

On August 10th the vessel proceeded from Charlevoix to Frankfort and with the wind on shore the temperature varied from 64° to 68°. On August 11th with the wind off shore the temperature varied from 54° to 57° from Frankfort to Manistee. It was 66° at Ludington, 64° at Pentwater. Below Pentwater the breeze changed to one blowing from the lake, and the temperature rose to 70° at Whitehall, 73° at Muskegon, 74° at Grand Haven. On August 12th with an off-shore wind a temperature of 64° was recorded between Grand Haven and Holland. At Saugatuck the wind had changed direction to the southwest and a temperature of 73° was observed. At South Haven it veered to the southeast with a temperature of 64°. On August 13th from St. Joseph to Chicago, the temperature varied from 70° to 75°, the winds being light and variable in direction. On the 14th with an on-shore wind the temperature of the water at Waukegan was 71°, at Racine 69°. On the 15th when leaving Milwaukee with an off-shore breeze the temperature was 62°.

The best illustration, however, was afforded August 21st, 22nd and 23rd. On the afternoon of the 21st when entering the harbor of Bruce Mines from the north channel, Lake Huron, the surface temperature of the water was 64°, the wind blowing from the southeast. On leaving the harbor the next morning with the wind blowing from the northwest, a temperature of 53° was observed. As the vessel crossed the channel and approached Cockburn Island, the water gradually acquired a temperature of 64°. After passing through Mississauga Straits it suddenly fell to 53° and then gradually rose to 65° off South Hampton on the Canadian shore of Lake Huron.

The mean surface temperature of the water flowing through the Straits of Mackinac was slightly less than at the nearest light

houses in Lakes Michigan and Huron during the period of observations at that locality, averaging 59.5° at White Shoal Light, 58.6° at Mackinac Island, and 62.1° at Poe Reef Light. At a depth of one hundred feet it was about eight degrees warmer than at the corresponding depths in the two lakes.

Bottom temperatures in Lake Superior taken by the office of the Lake Survey indicate that below one hundred feet that lake maintains a temperature of about 39° during the entire summer. In Lakes Michigan and Huron it remains below 50° at depths of 100 feet during the warmest months. There is some evidence that the water is warmer near the bottom than at middepths, but further confirmation is necessary before asserting it as a fact. The observations in Lake Erie indicated not only a marked increase in temperature near the bottom, but a strong subsurface flow nearly at right angles to any surface current that may have existed.

In making the observations the thermometer was incased in a brass cylinder with a valve in top and bottom opening upward, which would allow the water to freely circulate around the thermometer as it was lowered, but would close under an upward motion, thus permitting the water whose temperature was to be observed to be brought to the surface. This cylinder weighed several pounds and was at first used as a sinker.

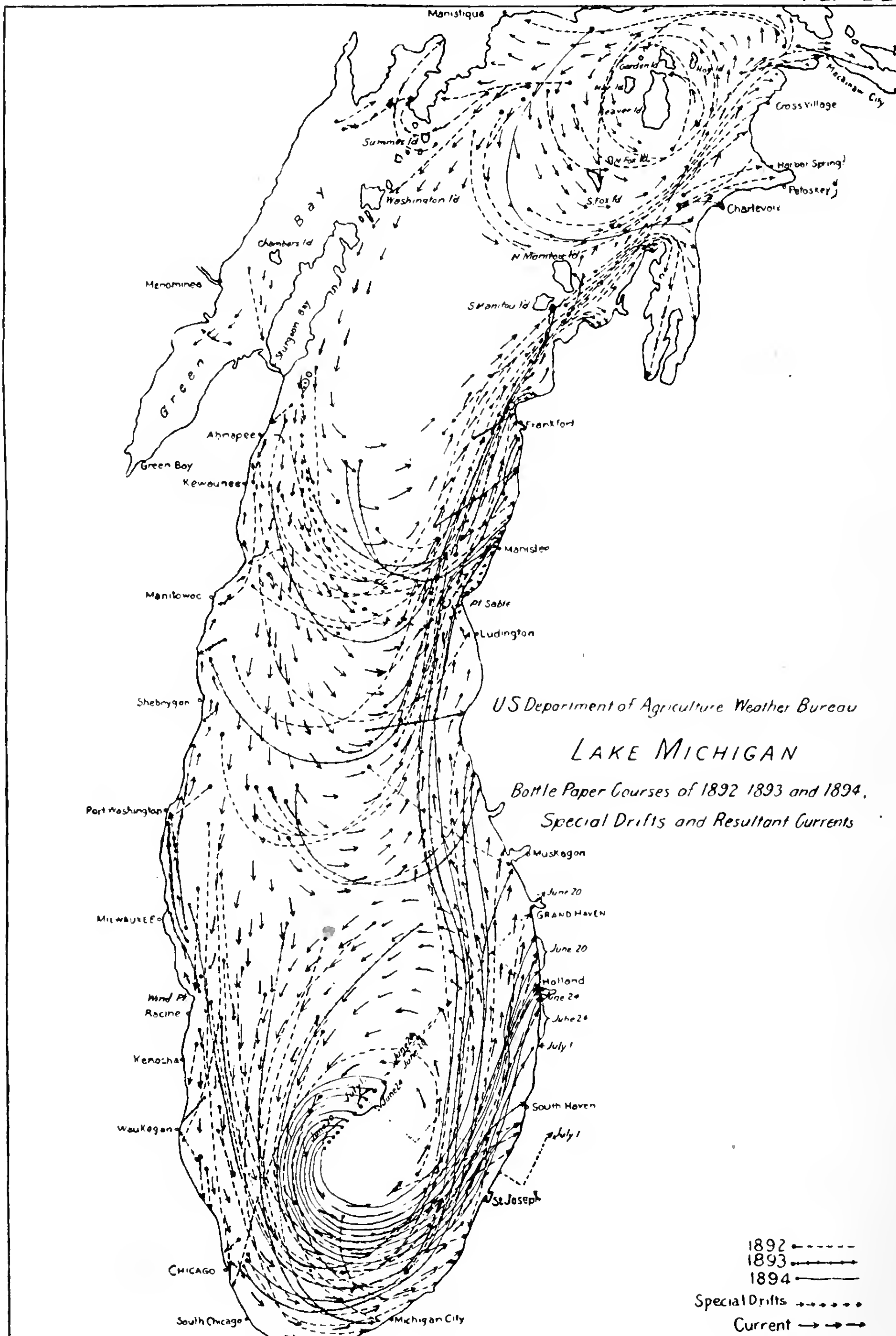
It was, however, noted in the Lake Erie observations that the wire to which it was attached at great depths instead of hanging vertically was inclined at an angle of over 30°. A heavy weight was then added and the observations repeated. The results tabulated were then obtained, but were not checked by a second set of observations as in the other soundings on account of the necessity to get into port that evening. The writer was also convinced that such an anomalous condition could only be temporary and that it would be useless to attempt to check the observations the next day.

In the rivers forming the outlets to the lakes, due to the rapid currents and consequent mixing of the waters, there is little difference in temperature between the water flowing on the surface and at the bottom, as shown by the observations in the Detroit River. The mean temperature of the Chicago River at Rush Street Bridge during the period of the observations averaged about six degrees colder than the surface temperature of the lake at the entrance to the harbor.

Currents.

The Weather Bureau of the Department of Agriculture in 1892, 1893, and 1894, made a series of observations on the surface currents of the Great Lakes by dropping from vessels at certain known localities, sealed bottles and noting the places at which they were recovered. These two fixed points were connected by curves assumed to be the paths of the floats. By repeating the observations a sufficient number of times it was expected that errors would be eliminated and the law governing the flow of the water discov-

PLATE I.


Manistique
Summer Id
Washington Id
Gardenk Id
Beaver Id
S. Fox Id
Cross Village
Harbor Spring
Petoskey
Charlevoix
Mackinaw City
N Manitou Id
S Manitou Id
Chambers Id
Menominee
Green Bay
Sturgeon Bay
Ahnapee
Green Bay
Kewaunee
Frankfort
Manistee
Manitowoc
Pt Sable
Ludington
Sheboygan
US Department of Agriculture Weather Bureau
LAKE MICHIGAN
Bottle Paper Courses of 1892 1893 and 1894,
Special Drifts and Resultant Currents
Port Washington
Muskegon
June 20
GRAND HAVEN
Milwaukee
June 20
Holland
June 24
June 24
Wind Pt
Racine
July 1
Kenosha
South Haven
Waukegan
July 1
St Joseph
1892
1893
1894
Special Drifts
Current
Chicago
South Chicago
Michigan City

ered. By these means surface currents in Lake Michigan during summer months were deduced which are shown in Plate I. According to this chart the main current flows southerly along the Wisconsin shore, then curves to the eastwardly along Illinois and Indiana and has a northerly direction on the Michigan side of the lake, with certain cross currents and eddies which are shown by arrows.

These deductions have heretofore been generally accepted by the public and even by engineers, but they have the fatal defect that the determination of a curve when only two points are known is a mathematical absurdity and the repetition of numerous mathematical absurdities can not establish a mathematical truth. They merely show that the data observed are not incompatible with a preconceived theory.

The fact that there is a Gulf Stream in the Atlantic Ocean with return equatorial currents, may be presumptive evidence of similar currents in all ponds, but the demonstration of such a theory requires more accurate demonstration than is afforded by the observations of the Weather Bureau.

A series of observations taken in 1897 at the various harbors on Lake Michigan in the Grand Rapids Engineering District demonstrated that the surface lake currents off the different harbors of Michigan generally corresponded to the direction of the winds though an irregularity in flow possibly due to eddy action was observable both at Ludington and Pentwater.

Observations of lake currents by the Milwaukee office at Milwaukee and Racine exhibited a similar tendency, so that it was assumed that if there was a rotary motion to the surface waters of the lake, it must be due to a rotary motion of the winds.

While the winds have a rotary motion about the center of low barometer the radius of the circle is too great to produce winds blowing in opposite directions on the Wisconsin and Michigan sides of the lake except possibly temporarily when the low center is directly over the middle of the lake, nor does the low barometer follow a sufficiently defined path across the continent to give any constancy to the directions of the winds in any particular part of the country.

The divergence in the directions of the winds which might possibly produce rotary lake surface currents was therefore sought in the land and lake breezes. It was for this reason that noon was selected as the time for taking the observations of the winds when the lake component of the winds should ordinarily be approaching its maximum, and that simultaneous observations were taken at northern, southern, eastern and western portions of the lake.

At all the localities selected these observations show that when a strong wind is blowing, the direction of the lake currents corresponds with the direction of the winds. When, however, the wind diminishes in intensity but continues in the same direction, the

current may flow in a direction opposite to the wind. At Chicago during thirty-three days a northerly current was recorded, during forty-one a southerly, and during eighteen days the current was inappreciable or moving on or off shore. At Grand Haven during forty-nine days there was a northerly current, during thirty-two a southerly, and during sixteen days one on or off shore.

For the currents to follow the curvilinear paths shown on the chart it would be necessary for the currents at Chicago and Grand Haven to flow in opposite directions. The record shows fifty days in which the currents coincided in direction at Chicago and Grand Haven, twelve days in which they flowed in opposite directions, and thirty days in which a northerly or southerly current at one station was accompanied by an on or off shore current at the other.

As no evidence was afforded during the period of observations of curvilinear surface currents it was considered advisable to investigate the data from which the original deductions were made by the Weather Bureau.

Considerable stress is laid on the bottles dropped from the steamer "Atlanta" on its trips between Chicago and Grand Haven in 1894 and the assumed paths of these floats are plotted on the charts. The bottles were thrown overboard June 20th, June 24th, and July 1st. Those placed in the water on June 20th were recovered between June 29th and July 16th, five in the vicinity of Grand Haven, and the sixth near Little Point Au Sable. Those of June 24th and July 1st were deposited further north than those of June 20th, and recovered between Holland and South Haven and the deduction is made that because the bottles which started from a more southerly location were recovered the furthest north therefore there was a rotary motion of the surface water. If the bottles had started on their journeys the same day this might be a logical assumption, but being in the water during different periods, the directions the wind was blowing at the time merits attention. The following is the recorded maximum force and direction of the wind from June 20th to July 20th, 1894, at Grand Haven obtained from the records of the Grand Rapids Engineer Office.

JUNE, 1894.

Date	Maximum Force	Direction
20	12	S. W.
21	18	S. W.
22	18	S. W.
23	16	S. W.
24	24	S. W.

25	18	S. W.
26	23	S. W.
27	12	S. W.
28	20	S. W.
29	14	S. W.
30	12	S. W.

JULY, 1894.

Date	Maximum Force	Direction
1	24	S. E.
2	20	N. W.
3	16	N. W.
4	24	N. W.
5	18	S. W.
6	25	N. W.
7	16	N. W.
8	18	N. W.
9	14	S. W.
10	17	S. W.
11	20	S. W.
12	27	S. W.
13	21	N. W.
14	12	W.
15	16	S. W.
16	16	S. W.
17	11	N. W.
18	12	W. N. W.
19	18	S. W.
20	18	N.

The paths of the floats as plotted are utterly incompatible with the observations of 1911. Those of June 24th exposed for six days to a southwest wind have a path during that period toward Chicago, when the wind veers to the southeast, they have an easterly motion, and when the wind blows from the northwest, they move northerly and are recovered just south of Holland. If, however, it be assumed that the floats move in the direction of the wind these discrepancies disappear. Grand Haven is northeast of the localities where the bottles were deposited and on June 20th and nine days thereafter, when the first bottle had been recovered near Grand Haven, the wind was blowing continuously from the southwest. The bottles thrown overboard on the 24th, at the same rate of travel would have been carried northwest of Holland by July 1st, and the wind then blowing from the northeast would have carried them further out in the lake, and then for six days out of seven veering to the northwest would have landed the bottles on

the shore near Holland. A similar plotting of the direction of the wind from July 1st would also indicate South Haven as the place to seek for those thrown overboard on that date. The observations for 1892 and 1893 are more difficult to analyze, as the assumed paths cross and run into one another in a confusing manner, but it is to be noted that the floats deposited in the lake close to the Wisconsin shore invariably are recovered on that shore, some north and some south of the point of deposition. Those deposited further out in the lake are usually recovered in Michigan.

Instead of these discrepancies causing any doubts in the author's mind as to the truth of his theory, they only cause him to introduce an extra current in the lake and to explain them by eddy action. Where there is a deep bay in a coast line eddies may develop and there is some evidence that there is eddy action at Ludington and Pentwater between Big and Little Points Au Sable, but a continuous eddy for a hundred miles along an exceptionally straight shore line is very improbable; moreover if Wind Point produced an eddy from currents moving southerly, the reverse current would be found on the Racine side of the point instead of north of it. A more rational assumption is that the motion of the floats to the Wisconsin shore was caused by the land breeze which develops at midday, while the floats deposited further from land and without its sphere of influence were driven by the prevailing westerly winds of summer on irregular courses across to the Michigan side of the lake.

The currents shown on the chart are not therefore logical deductions from the observations, but on the contrary are an attempt to force the data into conformity with a preconceived theory. In the opinion of the writer not only the observations presented in this paper, but also the data of the Weather Bureau clearly demonstrate that the surface currents of Lake Michigan tend to move in right lines, which are the resultants of the forces created by the winds blowing over it and which change in direction with every change in these resultants.

Wind blowing across a lake piles up the water on the shore toward which it is blowing and depresses it on the opposite shore, producing a difference in head, which is shown in the plots of gauge records of Lake Michigan, shown in Plate II. Due to this difference in head, the water from the bottom of the lake rises to the surface where the depression exists, and flows from the surface toward the bottom where the elevation of the lake is the greatest, and to compensate for this action there is a motion of the water along the bottom from the point of high potential to that of low. This action is demonstrated by the relatively low temperature of the water near shore during an off-shore breeze and its increase in temperature as it approaches the opposite side. The curvilinear path of the water of the lake instead of being a surface flow south on one side, north on the other, is therefore in the direction of the winds

on the surface, thence toward the bottom of the lake on the side toward which the wind is blowing, with a return current at great depths, the cycle being completed by the water rising to the surface at the point of beginning.

An interesting confirmation of this theory is afforded by the bacteriological investigations of the waters of Lake Michigan in reference to water supplies in the vicinity of Chicago. In a paper on the Relation of the Intake to Pure Water From the Great Lakes, presented by Mr. Charles B. Burdick, M. W. S. E., to the Illinois Water Supply Association in 1911, is discussed the desirability where surface cribs are used as in the case of Chicago of so locating port openings that water may be drawn from near the surface or near the bottom depending upon the direction of the currents.

It is stated that "upon the south shore of the lake it has been noted that the storms from the north quarter of the compass have the most detrimental effect upon the water supplies and that the strong southern winds have the opposite effect. The north wind is ordinarily accompanied by considerable wave action and an undertow which reaches the intake. At Gary, the lowest bacterial counts are obtained during the prevalence of a strong south wind. Under this condition, the shore water is apparently blown out into the lake on the surface, accompanied by a shoreward current along the lake bottom."

The Motion of Sand Along the Lake Shore.

As it has been asserted that the movement of sand along the shore of Lake Michigan was indicative that there were fixed currents in the lake, this subject was investigated, the piers constructed at the various harbors affording a means of determining the accuracy of the statement.

An examination of the accumulation of sand against the piers shows that while there is a movement of sand in both directions the greatest drift is usually found to the north of the harbors at the southerly end of the lake on both the Wisconsin and Michigan shores. This action is not as clearly marked at the northern harbors, but there is a greater drift from the south in several instances. The influence of sand points like the Au Sables and Point Betsy is also shown at the neighboring harbors, and there is a much greater movement of sand on the eastern shore than on the western.

The currents observed at the harbors were too feeble to have produced any extensive sand movements. At Mackinac Island when the flow through the Straits produces the most rapid currents, a maximum of 1.8 miles per hour was observed. This is the only locality, however, where their velocity was measured.

It appears probable that the movement of sand along the shore results from wave action rather than from lake currents, and that the excess of sand moving in a southerly direction at the southern end of the lake is caused by the greater reach of waves caused by

gales from a northerly direction than by those blowing from a southern quadrant.

The Influence of the Lake on the Temperature of the Surrounding Country.

When a current of air passes over a body of water the surface of the water either absorbs heat from the air or radiates it, dependent on the relative temperatures of the two media. If the water is colder than the air, but above 39° F. (its state of maximum density), the upper stratum absorbs heat, expands, and becomes lighter than the lower layers of water, while the lower stratum of air becomes colder than upper layers, and therefore denser. Under these conditions the passage of heat from air to water occurs slowly, unless the air and water be agitated so as to bring fresh particles in contact, as is the case when the air currents have sufficient force to produce wave action on the water. If the wind has sufficient force not only to produce wave action, but to raise the water surface on one side of the basin toward which it is blowing, not only are fresh particles brought in contact with the air, but the difference in elevation on opposite sides of the basin causes an upward motion of the water where the head is the least, which continuously brings the lower and colder layers of water to the surface to absorb heat from the air. The effect of water on the temperature of the air passing over it is therefore a function of the strength of the winds and the area and depth of the lake.

Lake Michigan has an area of over 22,000 square miles. Its greatest length is 307 miles, its width 118 miles, and maximum depth 870 feet, and it exposes an enormous water surface to the action of winds, and its depth gives an immense volume of water to absorb or radiate heat. Its effect may be appreciated by the following examples:

On July 3d when the air temperature attained its maximum of 96° at Milwaukee, the surface temperature of the water at that locality was 63°. On its passage across the lake the temperature of the air was reduced to 80° and the water acquired a temperature of 76°. On July 8th, when the air temperature at Grand Haven was at a maximum of 90° the temperature of Milwaukee was 80°, the surface temperature of the water at the two localities being 73° and 70°. The wind on the morning of July 3rd blew from the west at both localities and on the 8th from the southeast at Grand Haven and east at Milwaukee.

It will thus be seen that the lake currents have a most beneficial effect on the climate of the surrounding country, reducing the heat of summer and in general the cold of winter, in the direction the winds are blowing. There is, however, one exception to this beneficial action. When in winter ice has formed on the surface of the lake, a wind blowing for several days in one direction collects the ice in immense fields on the shore towards which it blows, as the ice, being lighter than water, can not follow the path of the

water particles except along the surface. Ice is a poorer radiator of heat than water, and intense cold results to the neighboring country.

DISCUSSION

Colonel Townsend: The temperatures of the water at certain depths were taken and are given below:

MACKINAC.

Depth. Feet.	Temp. Degrees.
0	64
20	64
40	62
60	57
80	56
100	55
120	55
140	54½
160	53
180	53
200	53

HARBOR BEACH, LAKE HURON

Depth. Feet.	Temp. Degrees.
0	68
20	64½
40	60
60	55
80	54
100	46½
120	45½
140	44½
150	44

LAKE ERIE.

Depth. Feet.	Temp. Degrees.
0	72
20	72
40	62
60	48
80	46
100	45
120	53
140	52
160	51
180	54

FRANKFORT, LAKE MICHIGAN.

Depth. Feet.	Temp. Degrees.
0	64½
50	58
100	47
150	46
200	46
250	46
300	45
400	48
500	47
600	48

The Detroit River was 67 degrees uniformly.

L. K. Sherman M.W.S.E. (Chairman): The data Col. Townsend has presented is important from a practical as well as scientific standpoint. For a long time a chart showing currents in Lake Michigan moving south along the west shore and north along the east shore, was very generally accepted. The observations reported in the paper this evening indicate that there are no permanently defined currents in Lake Michigan. This point is important inasmuch as it has a bearing on the pollution of water at the supply intake from sewer outfalls within a certain radius.

On the west shore of Lake Michigan, when piers are built, accretions are formed north of the piers and to a lesser extent south of the piers. This may be explained by the fact that the heaviest storm and wave action comes from the northeast and the movement of the drift is southward. The accumulations on the lee side of piers comes from sedimentation rounding the outer end and settling in the quiet waters. I would conclude from the paper that any currents in Lake Michigan were due to wind action and possible effects from barometric differences in the upper and lower ends of the lake.

We should be interested to hear Col. Townsend's conclusion as to the climate effect of drawing off a large amount of water from Lake Michigan.

Colonel Townsend: The result would be infinitesimal. The statement of the Board is as follows:

> "After extensive investigation and discussion of this subject the conclusion is reached that the effect on the climate of the Lake States, caused by the diversion of 10,000 second-feet of water through the Chicago Drainage Canal, whether beneficial or injurious, would be so small that it could not be measured by the most delicate instruments."

Prof. J. F. Hayford, M.W.S.E.: I have been much interested in this paper, especially in the part that Mr. Sherman has referred to. I have long been skeptical as to the existence of circular surface currents on Lake Michigan, and especially so as to the exist-

ence of returning currents, to the northward on the eastern side of the lake. I have been forced to study wind effects upon the Great Lakes in connection with an investigation on which I have now been engaged for four years. My studies have indicated that the surface flow is probably in the same direction as the wind, as a rule This has confirmed me in the belief that it is impossible to have on Lake Michigan the state of affairs indicated by the Weather Bureau charts of currents. I am, therefore, interested to hear Col. Townesnd's statement as to the way in which he believes that the Weather Bureau has registered a wrong conclusion in regard to the currents.

I would like to ask Col. Townsend about the statement made in his paper in regard to the constant variation in the location of the highest and lowest points of the water surface of the lake. From the data contained in the paper one would judge that the location of the lowest point would be fixed mainly by the surface winds. I believe it would also be influenced strongly by barometric effects. Would Col. Townsend give us more information on these points?

Colonel Townsend: There is a constant variation of the level as shown by the gauge readings which will bring it out much better than I can explain it. These readings were taken for a series of thirty days.

W. E. Williams, M.W.S.E.: Is there any explanation of the rise and fall of the water in Lake Michigan in a short space of time. We hear sometimes of a variation of four feet. What would you consider the cause of such a fall?

Colonel Townsend: I have never found a satisfactory solution. They sometimes occur in perfectly calm weather. I have seen them myself of a height of at least a foot, but I have never seen a satisfactory explanation of the cause. They have been discussed by many people. I strongly suspect that the high bottom temperatures observed in Lake Erie may have arisen from such action. On a perfectly calm day there is no appreciable difference in the level of a lake. I have heard it explained that this action is due to variations of barometric pressure. Lyman E. Cooley investigated the matter some fifteen years ago, and I don't know but that Col. Judson made some remarks on the subject.

Bottle floats were used by the weather department for ascertaining the surface currents.

The means employed for getting the temperature of the water at different depths may be of sufficient interest to merit explanation. A brass tube about a foot or foot and a half long with a valve in both the top and bottom opening upwards was employed. These valves would allow the water to circulate around the thermometer as it was lowered, but would close when raised, thus permitting the water whose temperature was to be observed to be brought to the surface.

Mr. Sherman: Is there anyone from the opposite side of the lake who can explain the action of erosion there?

Colonel Townsend: The harbors on the opposite side indicate

a movement of sand, which is much greater than on this side. The movement is very strong at Grand Haven on both sides of the pier, and it is always stronger on one side of a harbor than on the other. There is a much greater movement of sand on the east shore than there is on the west shore. As you approach the north end of the lake there is very much less motion of sand, and no decided tendency to excess motion in either direction. At Charlevoix there is more action from the north than from the south. The northern beaches are composed of heavier gravel than those at the lower end of the lake.

Professor Hayford: I would like to tell you a little about a theory I have had in mind as to the effects of barometric pressure upon the lake levels. On a certain day the barometric pressure here at Chicago was 0.4 inches greater than at Mackinac. On that day in order to have equilibrium, it was necessary that the lake level should be about 0.4 feet lower at Chicago than at Mackinac, since an inch of depth of mercury produces about the same pressure as a foot of depth of water. So in general, any barometric gradient must produce the corresponding reverse slope in the water surface. Using this theory, I have been following the observations rather closely in an attempt to separate the barometric effects upon lake level from the wind effects. I think I am having some success.

Buffalo seems to be a point on the Great Lakes where the fluctuations of level produced by winds are unusually large. In studying the data at Buffalo it appears that there are many cases in which the mean level is five inches or more, higher or lower, on a certain day than on the preceding day.

I believe from my studies on the data that when both the wind and barometric effects are taken into consideration at the same time it will be possible to take most of the mystery out of the apparent irregularities in the fluctuation of level on the lake surface. Please note that it is stated that the wind and barometric effects must be studied at the same time. If either is studied alone the mystery will remain.

In studying Lake Michigan and Lake Huron as one lake, I have found indications that the wind blowing through the Straits of Mackinac has an injector action tending to pump up Lake Huron and pump down Lake Michigan by the same amount when the wind at the Straits is from the west. The action is reversed, of course, for an east wind.

Colonel Townsend: I have observed a difference of level of six feet on Lake Erie between Buffalo and the other end of the lake. There has very recently been a difference of three feet on Lake Michigan between Milwaukee and Grand Haven. Referring to the relative levels of Lake Michigan and Lake Huron, the mean results covering a long period of years show that Lake Huron is about .02 of a foot higher than Lake Michigan for one part of the year, and for the balance of the year Lake Michigan is higher.

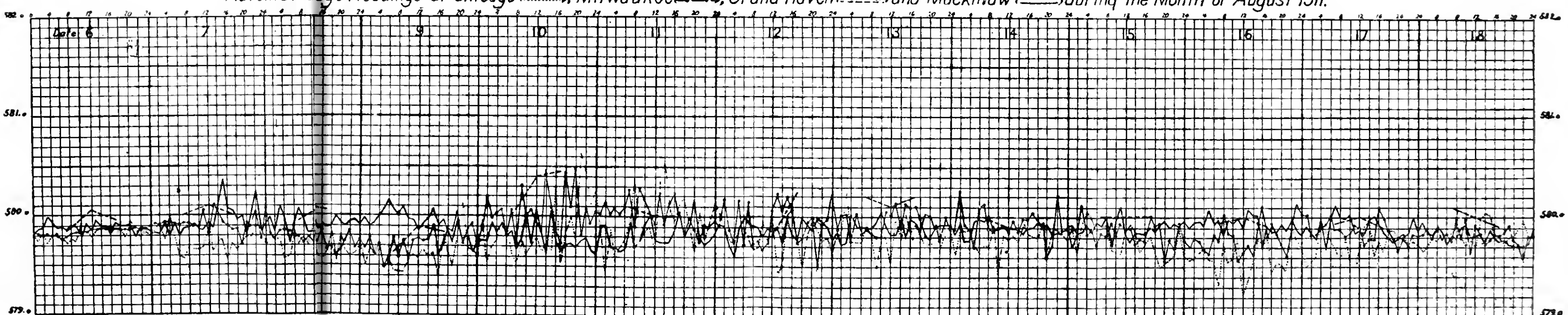
Professor Hayford: My investigations are still in progress.

WESTERN SOCIETY OF ENGINEERS.
Vol. XXI. No. 4. April, 1916.
Townsend — Currents of Lake Michigan.

LAKE MICHIGAN

PLATE II

Automatic Gage Readings at Chicago (..........), Milwaukee (—·—·), Grand Haven (Staff Reads) and Mackinaw (——) during the Month of August 1911.



I will be glad to give the Society my figures, in due time. I could answer the question more exactly if I had my computations at hand. I have figured on the wind effects upon water levels on Lake Michigan. I am not depending upon theory, but upon observations extending over each day for twenty-eight months. My present statements are, however, based upon preliminary computations from eight months only.

You will notice from Col. Townsend's statement that Lake Huron is higher than Lake Michigan in some parts of the year and Lake Michigan is higher for the remainder of the year. This bears out my beliefs to a certain extent. The prevailing winds are different in different months and so should produce prevailing differences in level, dependent upon the time of year.

Mr. Williams: Colonel Townsend, is it not true that Lake Superior is about 20 feet higher than Lake Michigan, and would not the effect of this storage of water in Lake Superior make it have an effect on Lake Michigan?

Colonel Townsend: That has no relation to it whatever. The water flows from Lake Superior the entire year at approximately the same rate. The cycle of water levels in Lake Superior is different from that of Lake Michigan or Lake Huron; the flow, moreover, through the Straits of Mackinac is at times so great as to make the flow of the St. Mary's river appear insignificant.

SMOKE ABATEMENT AND ELECTRIFICATION OF RAILWAY TERMINALS IN CHICAGO

DR. W. F. M. GOSS, M. W. S. E.

Chief Engineer, Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals.

Presented December 20, 1915.

(The address as given by Dean Goss was extensively illustrated by lantern slides. The illustrations served not only to picture the character of the City of Chicago and of its railroad establishments, but also as a means of presenting diagrams and tables of figures setting forth the more important quantitative results derived from the investigations described. As it is impracticable to reproduce herewith any considerable number of these slides, it is quite impracticable to give a verbatim report of the address. The following summarized statement covers some of the more available matters presented:)

For many years there has been in Chicago a popular feeling that Chicago's atmosphere is more smoky than it need be, and that the locomotives of Chicago's railroads contribute considerable percentage of the total pollution. As an outgrowth of this feeling, a committee was appointed in 1911 by the Chicago Association of Commerce to report to the Association concerning the practicability of electrifying the steam railway terminals of Chicago as a means in smoke abatement. This committee deliberated for the greater part of a year and rendered a report. In effect, the report found that it was technically feasible to electrify the railway terminals of Chicago; that when electrification had been accomplished it would be of advantage to the railroads; that the electrical operation would be safe; but that any plan for electrification would be difficult to carry through because of its financial requirements. The Presidents of the railroads of Chicago declined to accept the findings of this report. They said that the conclusions of the committee were merely the conclusions of the individual members of the committee; that the members of the committee had had no information upon which to base their recommendations, not possessed by other people; and that consequently no great credence was to be given their conclusions.

Out of the discussions which were thus projected, it was finally agreed that if the Chicago Association of Commerce would organize a committee of investigation and would conduct a broad inquiry into the whole matter of atmospheric pollution, of the sources of smoke, and of the technical and financial practicability of electrification, the railroads of Chicago would undertake to pay the costs. As the result of this agreement, the Committee of Investigation on Smoke

Abatement and Electrification of Railway Terminals was brought into existence. This committee has now accomplished the work assigned it, and its results have been published in the form of a 1200 page report.

There has been some criticism concerning the procedure of the committee, especially with reference to the program underlying the committee's estimates of cost. With reference to this aspect of the committee's work, it should be observed in the beginning that the whole problem of the committee, the report of which I am to discuss, was based upon the contention of the city council that the steam locomotive should be eliminated from the City of Chicago. The complete elimination of the steam locomotive was interpreted to imply the complete electrification of the railroads of the city. The committee's action in this matter was, therefore, responsive to the prescription which was given the committee, and its procedure in this respect was not dependent upon its choice.

I shall not attempt to refer to the work which has been done in smoke abatement, although the committee's investigations in this field were extensive and interesting. I will only set forth some-

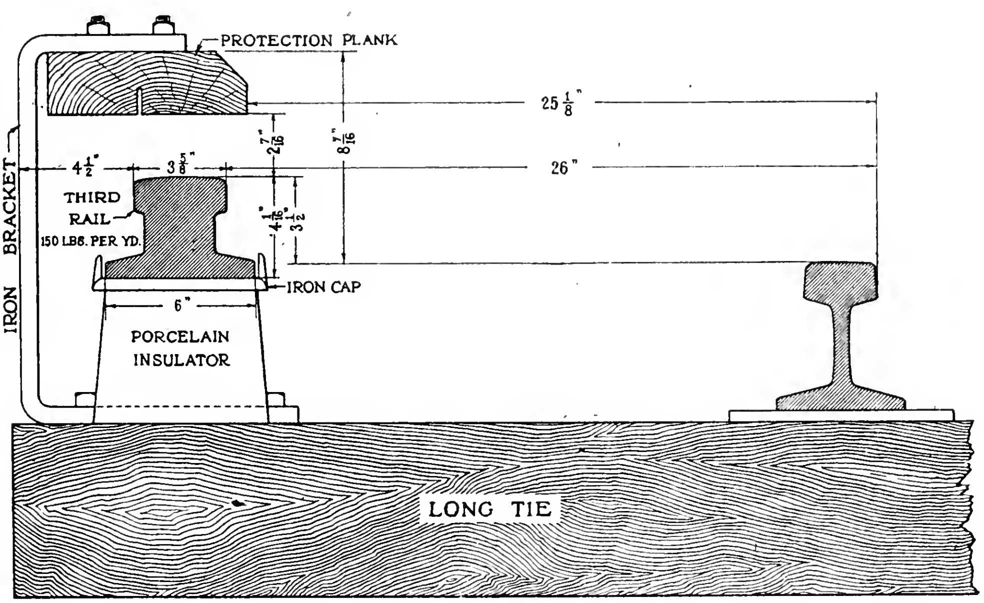


Fig. 1. Over Running Third Rail Installation. Position of Third Rail with Reference to Track Rail, Third Rail Section, and Protection Provided.

thing of the processes and the results of the committee's study of the problem of electrification.

One of the early questions which the committee sought to answer was: What has been accomplished in the electrification of steam railroads? In answer to this question, a thorough study was made of the actual electric installations in this country and in other countries on roads of steam railroad standards, the results of which would easily make an evening's story. Briefly stated, it

appears from this study that there are several sorts of electric traction systems which might be proposed for the Chicago terminals. With regard to character of electric current used, electric traction systems may be classified as direct current systems and alternating current systems. Direct current may be used at voltages varying from 500 to 2,400 or even more. Alternating current may be single phase or three phase, and it may be classified as to frequency as to voltage. A voltage of 11,000 is commonly used with alternating current systems. With reference to the means employed to carry the current to locomotives and motor cars, electric traction systems may be classified as third rail contact systems and overhead contact systems.

In connection with a study of electrification as it might be

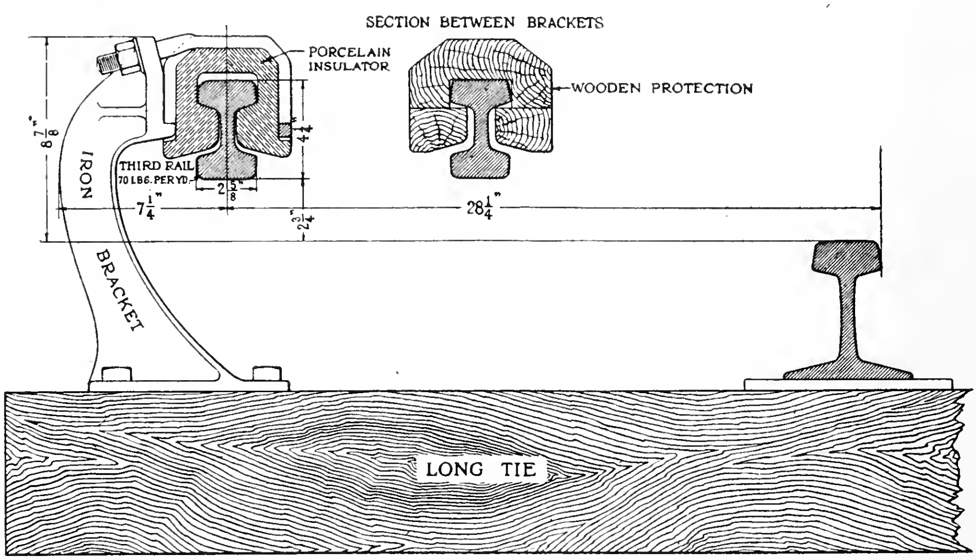


Fig. 2. Under Running Third Rail Installation. Position of Third Rail With Reference to Track Rail, Third Rail Section, Supporting Bracket and Insulator.

applied to the Chicago terminals, it is important to understand clearly the changes in physical conditions which would be introduced by the installation of either the third rail, or the overhead contact systems. In a third rail system the third rail and its protection stands 8 or 9 inches above the track rail and at a distance of about 2½ feet from the gauge of the track rail. This position of the third rail makes it an obstruction of the free movement of trainmen, especially in yards, and the objection is urged by many railroad men as a serious one in Chicago, where yard tracks constitute a large percentage of the total trackage to be electrified.

The third rail at switches, where special track work occurs, and at highway and railroad crossings at grade must be interrupted, presenting gaps over which trains must coast, or in case the gaps are long, which must be bridged for continuous contact by the in-

stallation of an overhead conductor rail. The electrification of the Chicago terminals through the use of the third rail system would present 737 gaps aggregating about 16 miles for which the overhead conductor rail installation would be required. Including the shorter gaps which could be coasted over, there would be approximately 4,000 gaps totaling about 56 miles in the third rail in the Chicago terminals. It has been found also that there are about 75 miles of track in Chicago which because of physical conditions could not be equipped with any known form of contact system.

If choice were to be made of an overhead contact system using high voltage current, clearance is a matter of great importance.

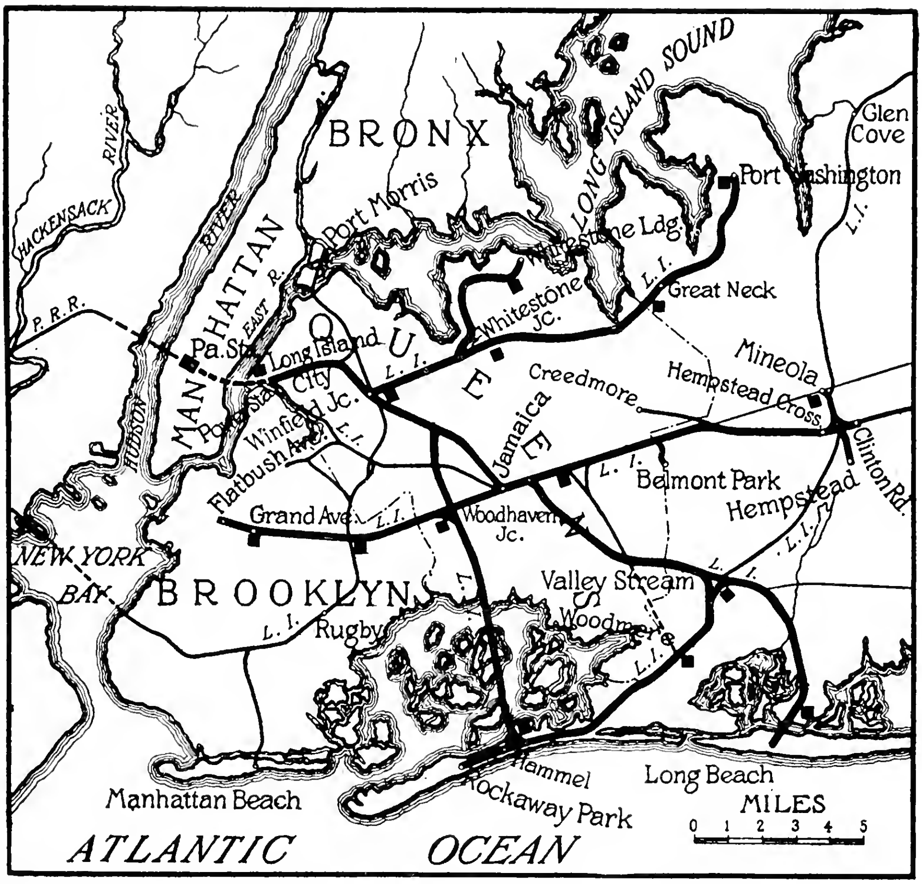


Fig. 3. Electrified Lines of the Long Island Railroad.

Not only must the wires be placed at a suitable height to permit the contact to be made from a moving train, but it is desirable that they be sufficiently high to allow a trainman standing on the top of the highest car to give signals with a lantern swung overhead. This requirement demands that the contact wire be maintained at a height of approximately 25 feet above the track rail. Overhead obstructions, such as bridges or viaducts, which can not be raised to a height sufficient to permit the maintenance of this clearance, require the wire to be depressed, in many cases to the minimum

height of 16 feet 6 inches. There are 222 overhead structures in Chicago, which do not afford sufficient room for the installation of the overhead contact at the safe clearance of 25 feet.

Overhead contact systems involve the installation of supporting structures at intervals of from 150 to 300 feet on tangent track and at lesser intervals on curves. The structures consist of structural steel or tubular poles set on either side of the tracks and of structural steel or wire bridges supported by the poles or posts. Suspended from these bridges are the messenger cables and contact wires.*

The overhead contact construction of whatever type is complicated and not particularly pleasing to the eye, and it constitutes some obstruction to vision along the right-of-way. It is conceivable that if adopted for general use throughout the terminals of Chicago, it might offend those who have waged war on the presence of overhead wires for other purposes in our great cities.

These considerations suggest the range of choice which may be exercised in the selection of a contact system for use on the railroad terminals of Chicago.

Concerning rolling equipment with which to operate the Chicago railway terminals, it may be said that electric locomotives have been designed and built for all classes of passenger, freight and switching service. Motor cars, whether operated singly or in trains under multiple unit control, have proved their value for handling passenger traffic involving frequent train movements and short runs between stops.

Passing from the details of construction to a more general view of electrification projects, we may consider for a moment a few of the installations that have been widely discussed. Let us refer to Figs. 3 to 8, inclusive.

The West Jersey and Seashore Railroad early electrified one of its two lines from Camden to Atlantic City, New Jersey, a distance of sixty-five miles. This installation was undertaken chiefly to ascertain the economic possibilities of main-line electric traction and its effect upon traffic. Electric operation is conducted wholly by multiple-unit motor-car trains. Freight trains and a number of passenger trains are operated over portions of the electrified trackage, but by steam locomotives.

The electrification of the Long Island Railroad is one of the most important electric installations in the United States. It operates electrically a network of lines covering the western end of Long Island, and delivers heavy commutor and excursion traffic to the Brooklyn and Manhattan terminals. The Long Island Railroad electric operation, however, is confined to multiple-unit service. It handles no freight or heavy passenger service, and is comparable to our suburban operation.

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*A series of illustrations showing different types of overhead construction were shown upon the screen.—Ed.

Important among the projects to be referred to are the three railroad electrifications of New York City.

The New York Central and Hudson River electrification, supplies the means by which passenger trains are operated electrically into the Grand Central Station of New York City. A study of the conditions under which this road operates, however, reveals the

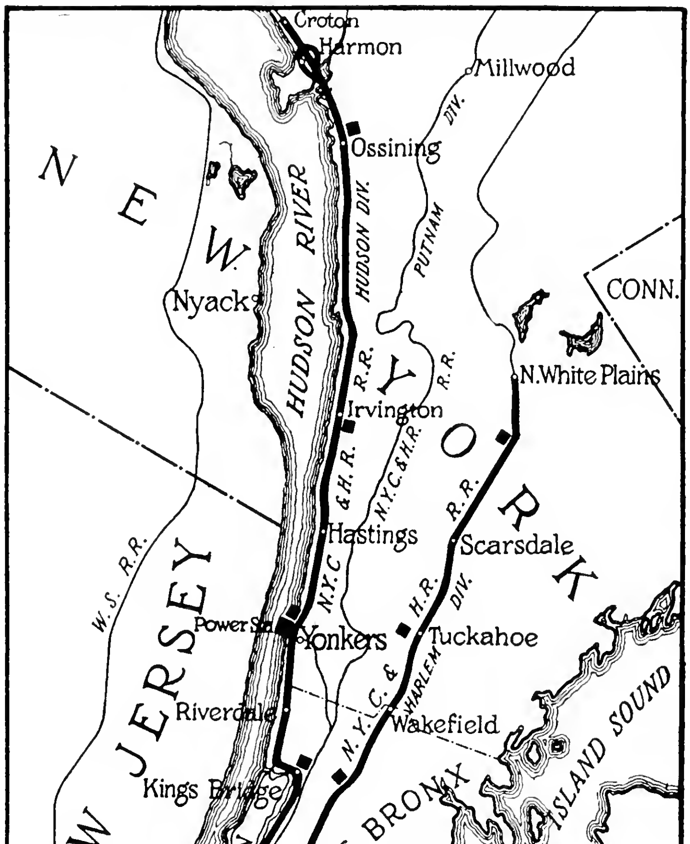


Fig. 4. Electrified Lines of the New York Central & Hudson River Railroad.

fact that it is not comparable with the situation to be met in Chicago. The electrification of the New York Central Railroad was made necessary in order to eliminate the smoke and objectionable gases arising from steam locomotives in the long tunnel entrance to the Grand Central Station. The density of traffic had be-

come so great that steam operation in this tunnel was no longer practicable. The electrification of the main line sections beyond the portals of the tunnel was necessary in order to secure continuous operation of the large number of local trains to the end of runs within suburban limits. It is a passenger terminal project.

The New York, New Haven and Hartford Railroad undertook electrification primarily for the same reasons as those which influenced the New York Central Railroad. Its extension to main lines beyond the limits of the terminal section has been due primarily to the operating necessity of conducting continuous service to the limits of the local service zone. The density of traffic over the

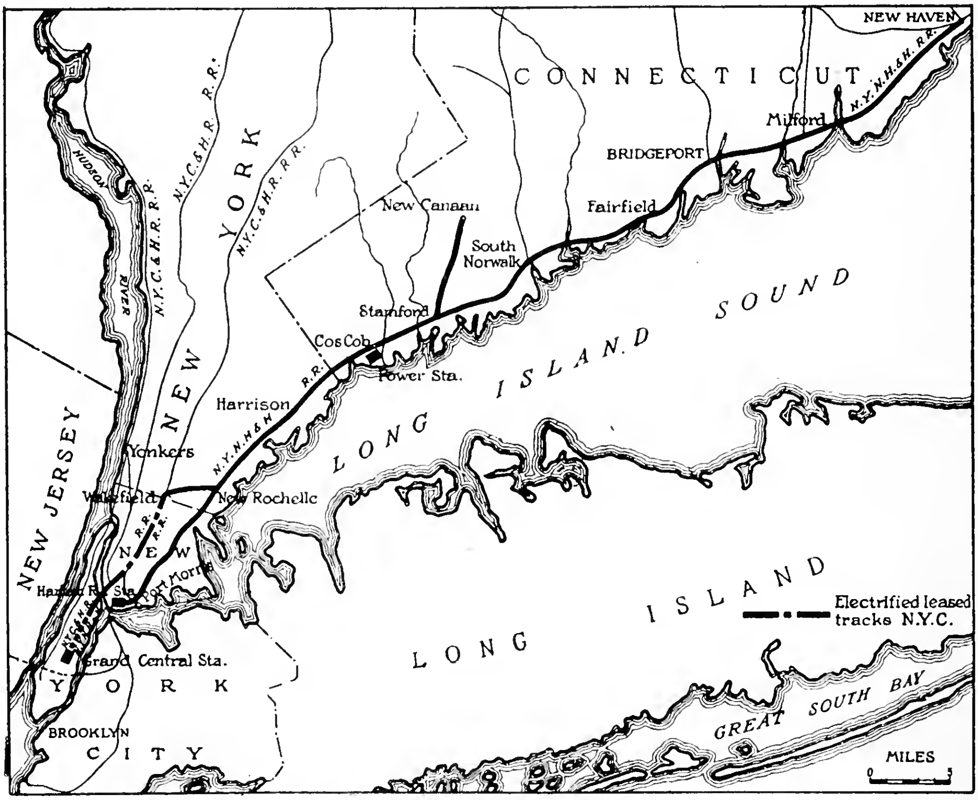


Fig. 5. Electrified Lines of the New York, New Haven & Hartford Railroad.

electrified sections of this road, as is the case with the New York Central, is very great.

The Pennsylvania Railroad tunnel under the Hudson river to the terminal station on Manhattan Island, and thence continuing under Manhattan and under the East river to Long Island was electrified as an operating necessity. Like the other electrifications already mentioned, it is not comparable to the Chicago situation, and the reasons which prompted it do not exist in Chicago.

It will be noted that justification for all of these projects is to be found in density of traffic requiring frequency of movement, or in tunnel operation, and that the service is chiefly passenger service.

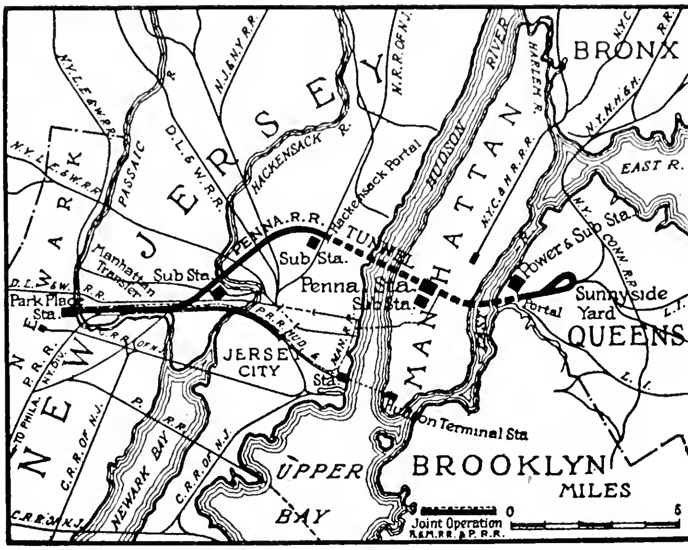


Fig. 6. Electrified Lines of the New York Tunnel Extension of the Pennsylvania Railroad.

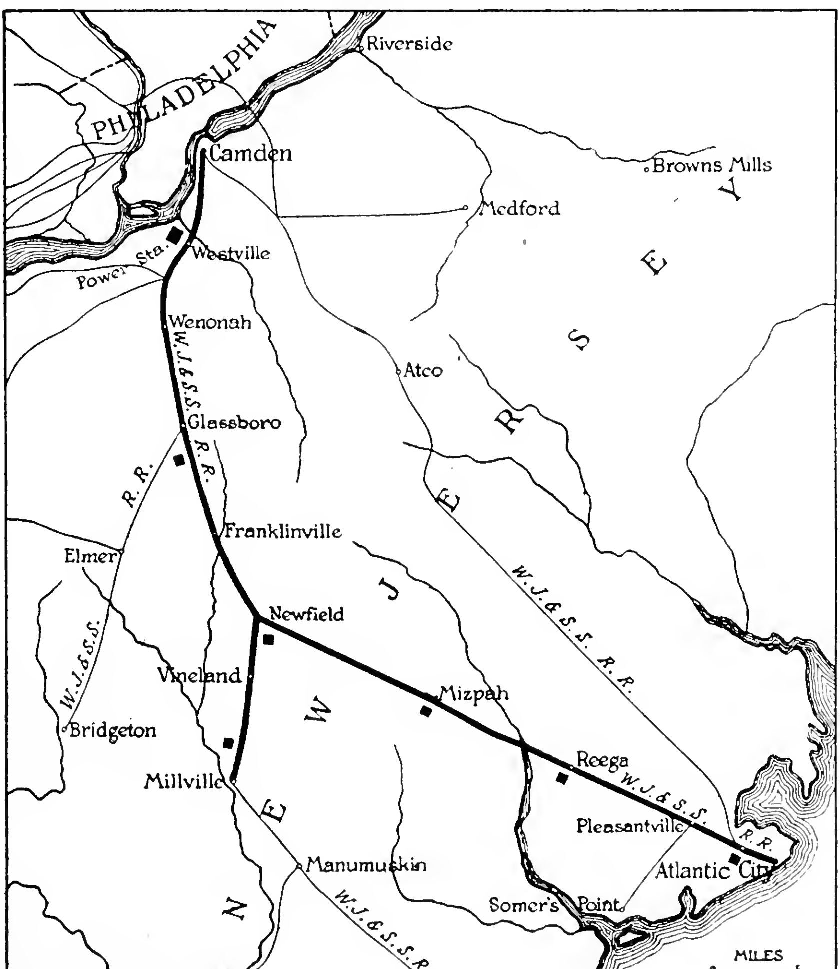


Fig. 7. Electrified Lines of the West Jersey & Seashore Railroad.

In Chicago the density of traffic over much of the trackage is low. There are no tunnels, and the greater part of the total traffic is freight and freight switching.

The number of steam railroad electrification projects in America and in other countries is 37. The combined electrified mileage of these roads is 3,000. The number of different railroads represented in the activities of the Chicago terminals is 37, and the mileage which is involved in the committee's plan of electrification in Chicago is 3,439.

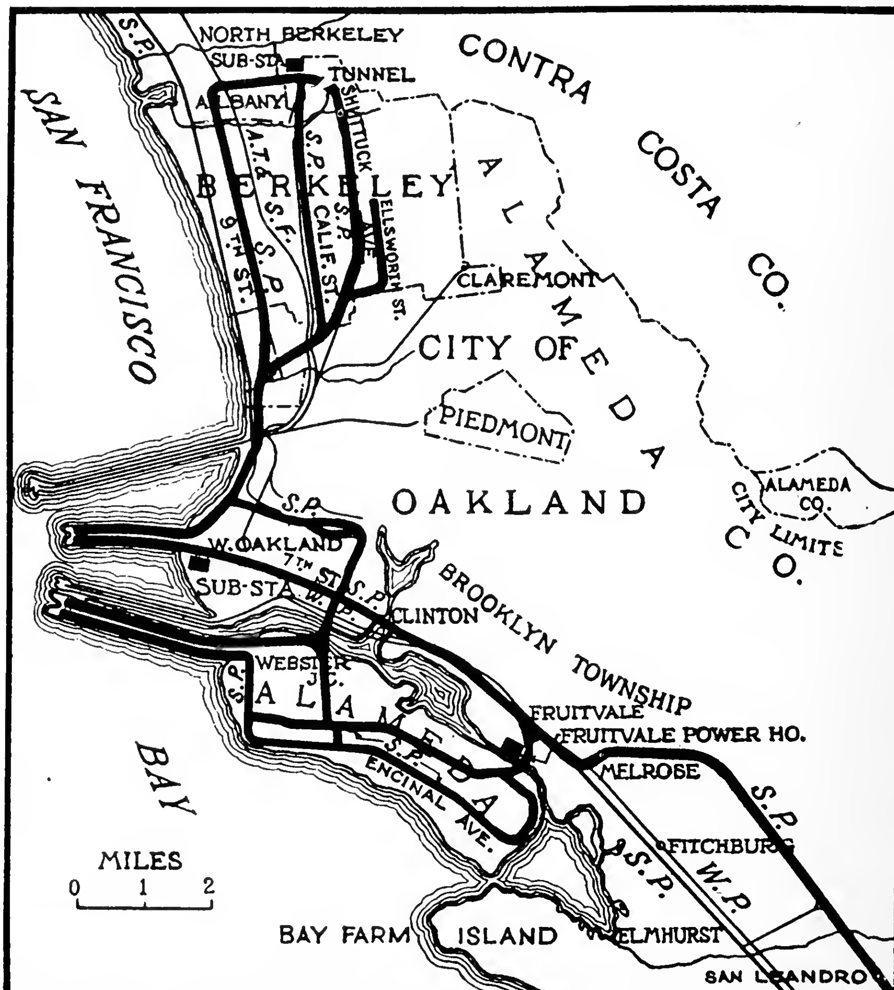


Fig. 8. Electrified Lines of the Southern Pacific Railroad.

The record of work already accomplished in electrification is significant in that it presents no instance in which a steam railroad occupying surface or elevated lines has been electrified primarily to avoid the pollution of the atmosphere of the city. It shows also that nowhere in the world has a railroad having a city terminal, which from an operating standpoint has been satisfactory, changed its operation from steam to electric.

At the beginning of its investigation the committee undertook a detailed study of the area, trackage and railroad facilities involved in the proposed plan of electrification. A discussion of some of the historical facts which this study revealed would be very interesting, but I shall pass over these and confine my remarks to the problem involved in electrifying the terminals as we find them today.

The committee made a detailed study of operation, traffic and train movements, and upon the basis of facts thus obtained has determined the amount of electric energy which would be required for

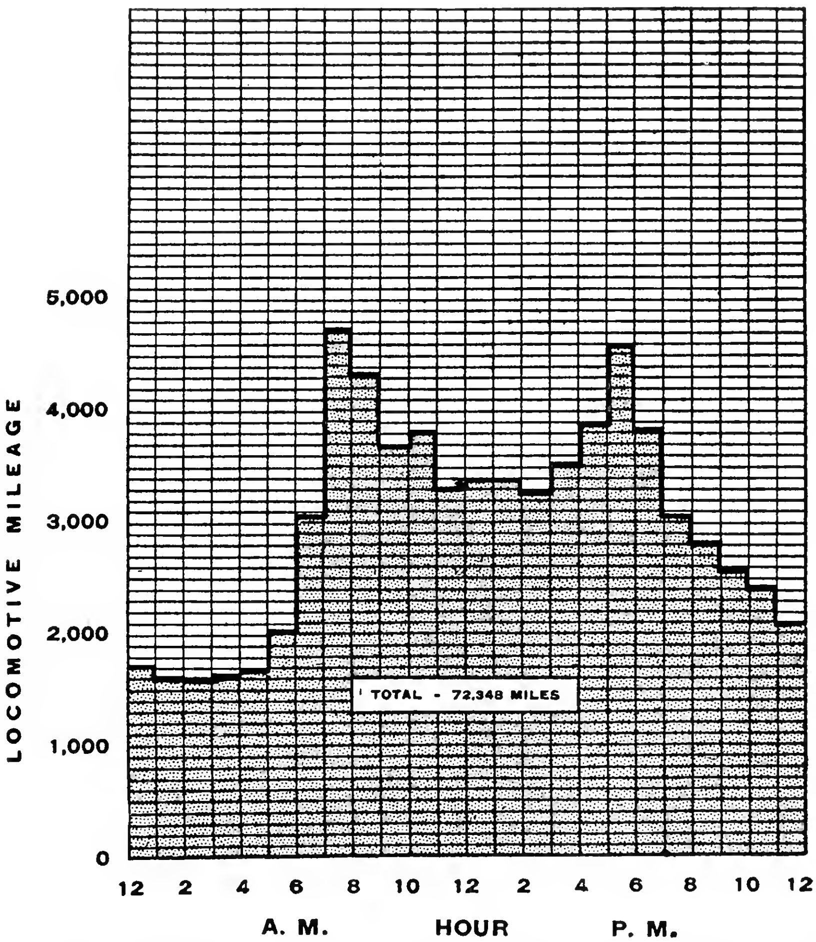


Fig. 9. Traffic Diagram. Total Locomotive-Mileage for the Average Day for Steam Operation in All Classes of Service Within Area of Investigation.

the operation of the terminal electrically. Underlying this determination are certain fundamental facts which will be of interest. Figs. 9, 10, 11, 12 and 13 show in graphical form the locomotive-mileage performed, the number of ton-miles handled, the number of tons of coal burned, the total number of locomotive-hours of service, and the energy required for the electric operation of the Chicago terminal.

The committee also made a study of the growth in track mileage,

passenger traffic, and freight traffic which may be expected to take place in the ten years following 1912. This estimated growth is based upon the rate of growth which took place during the 10-year period prior to 1912. As a result of this study it is estimated that the trackage within the committee's area of investigation will increase approximately 31 per cent during the 10-year period from 1912 to 1922, or from 3,988 miles in 1912 to 5,220 miles in 1922. The number of through passengers handled will increase from 11,000,000 in 1912 to 15,500,000 in 1922, or about 40 per cent. The

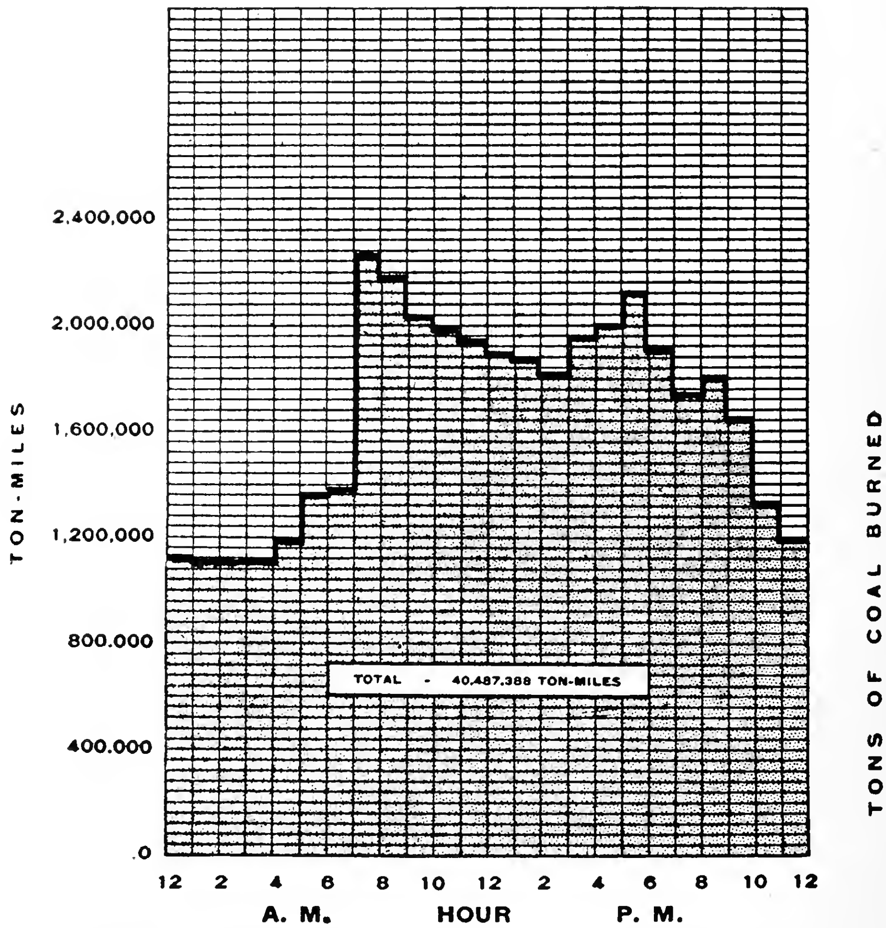


Fig. 10. Traffic Diagram. Total Ton-Miles for the Average Day for Steam Operation in All Classes of Service Within Area of Investigation.

number of suburban passengers will increase from 42,000,000 to 45,000,000 or 7 per cent. The total number of passengers will increase from 53,000,000 to 60,500,000 or 14 per cent. The number of tons of freight handled through freight houses will increase from 8,500,000 in 1912 to 10,140,000 in 1922, or 19 per cent. The number of freight cars received and forwarded will increase from 15,000,000 in 1912 to 21,000,000 in 1922, or 41 per cent.

In order to provide for this growth in the activities of the

Chicago railroad terminal, it was necessary for the committee to base its estimates of cost upon the electric establishment which would be required to handle the traffic at a date when it might be expected that the electric installation would be completed. This date as fixed by the committee's program was 1922.

Another problem which involved careful study was that of fixing the limits of the electrified trackage for each railroad. It was early determined to accept, as a principle to be recognized in

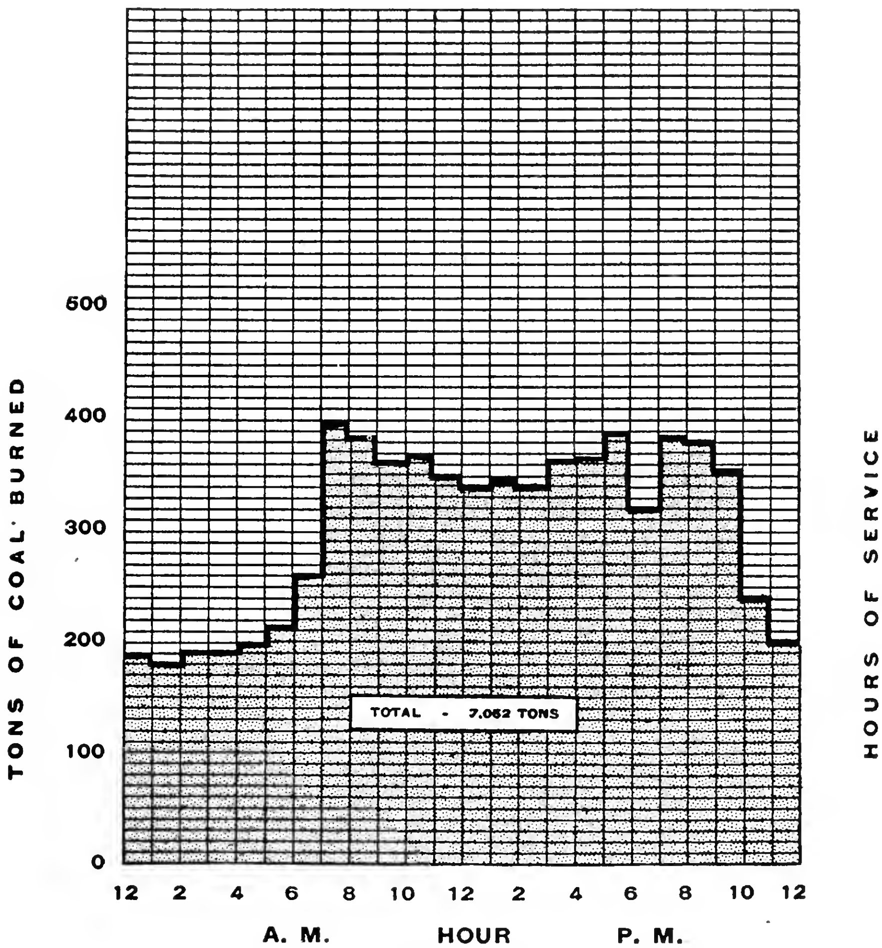


Fig. 11. Diagram of Coal Consumption. Total Tons of Coal Burned During the Average Day for Steam Operation in All Classes of Service Within Area of Investigation.

fixing limits, the inclusion of all tracks within the corporate limits of the city. While from the standpoint of atmospheric pollution the effect of electrification in many portions of the city would be negligible, the jurisdiction of the city council extends over the entire territory of the city, and in the event that electrification is required by act of the council, it would either initially or ultimately apply to all trackage within the city. Assuming, therefore, that electric operation of a railroad between the city terminus and the outer

limits of the city is necessary, the precise point at which electric operation should terminate still remains to be fixed. It can not be assumed that the boundary of the city is in all cases the strategic point to be observed for such a purpose. A railroad having an important suburban passenger service originating beyond the city limits, if required to electrify to the city limits, would, for the greater convenience of its patrons, be justified in continuing its scheme of electrification on to some more distant point. A railroad operating within the city might need to go a considerable distance beyond the limits of the city to find available land upon which to

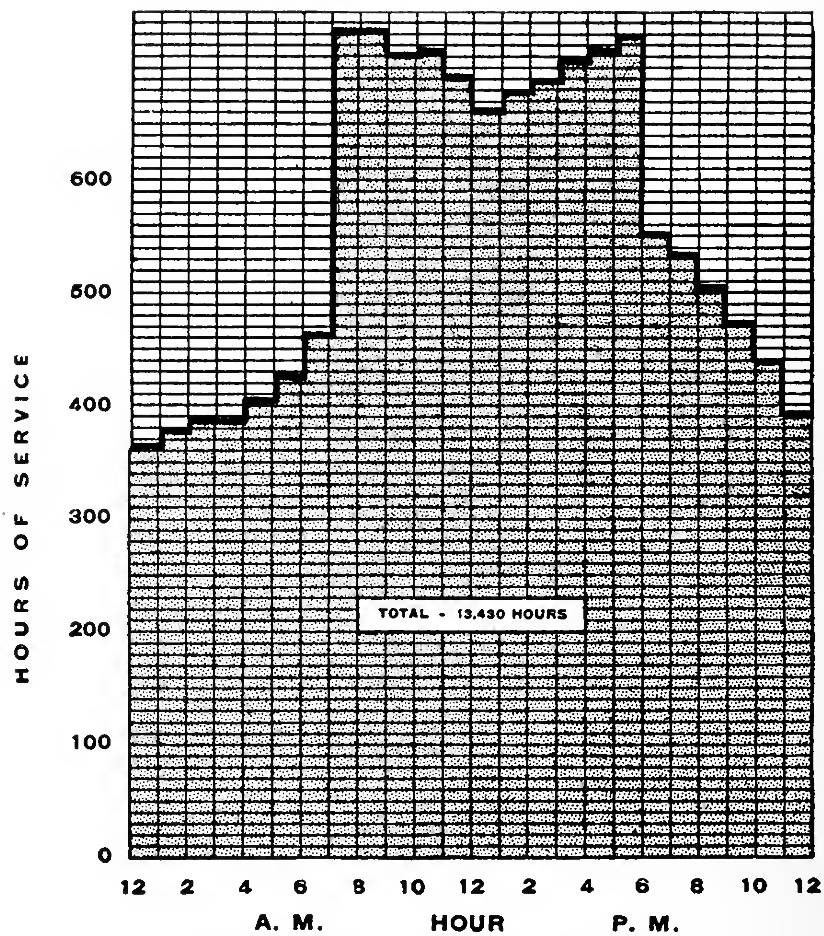


Fig. 12. Traffic Diagram. Total Locomotive-Hours of Service for the Average Day for Steam Operation in All Classes of Service Within Area of Investigation.

develop the necessary transfer yards and other terminal facilities.

The committee gave careful consideration to these and other conditions affecting each of the railroads involved in the proposed plan of electrification. The outer limits of complete electrification were fixed for each railroad substantially upon the basis of the following considerations:

1. In the case of each railroad, it has been sought to terminate

complete electrification at the first satisfactory point beyond the limits of the city.

2. In the case of railroads having large yards, repair shops, or other facilities outside of the city and within a short distance therefrom, the location of such facilities has been accepted as a reasonable terminus for complete electrification.

3. In the case of railroads presenting no feature which might suggest a choice of location, a point has been selected as near the

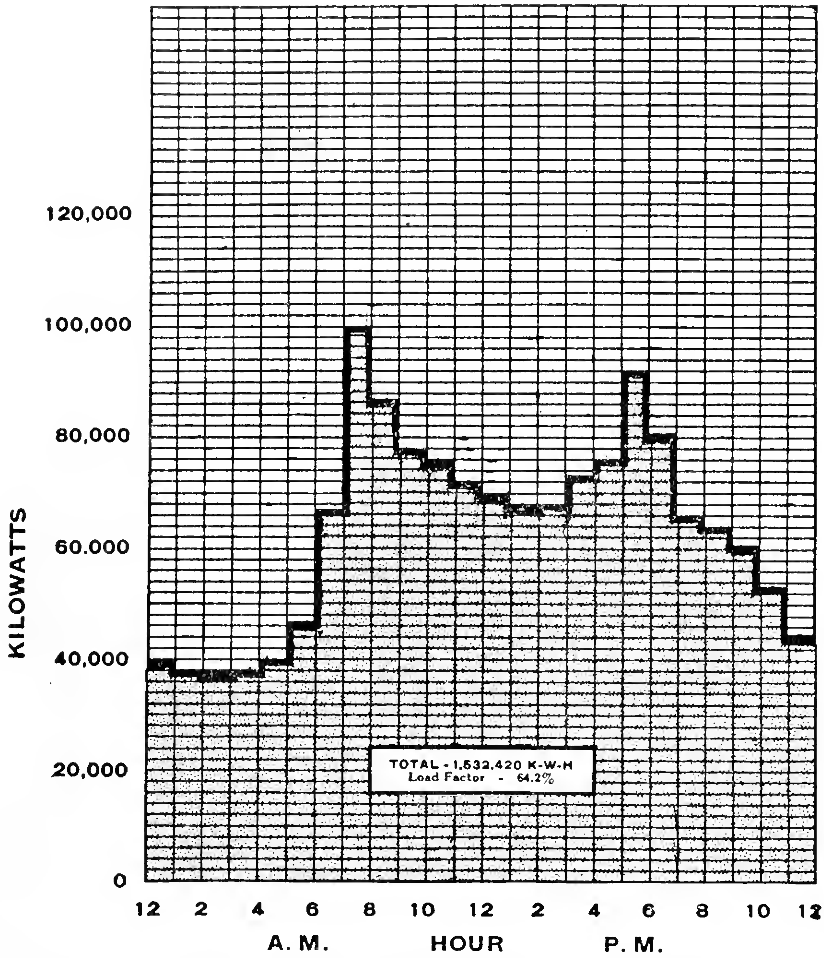


Fig. 13. Energy Chart. Total Kilowatt-Hours at the Pantograph for the Average October Day for 11,000-Volt A. C. Operation, All Classes of Service.

city limits as practicable, which gives promise of supplying land upon which to develop the necessary terminal and transfer facilities.

The fixing of limits under these principles has necessarily led to differences of opinion. There was danger on the one hand that the estimates of cost might be overloaded by adopting too large a plan. There was danger, on the other hand, by adopting too meager a plan, of having an establishment which, from an operating point of view, would be unmanageable. The committee did what it could

to escape the danger of both these extremes. The map which is presented as Fig. 14 shows the proposed limits of electric operation as they were fixed by the committee.

By comparing the extent and activities of the railroad establishment included within these proposed limits of operation with electrification projects elsewhere in the world, we may note the following significant facts:

1. The mileage of track involved by the proposed electrification of the Chicago railroad terminals is nearly twice as great as the mileage of all existing electrically operated steam railroad track in America, and exclusive of foreign light service lines, is about 15 per cent greater than the combined total mileage of all existing electrically operated steam railroad track in the entire world.

2. The number of through passenger trains required by the traffic of the Chicago terminals is 85 per cent of the total number of such trains at present operated electrically on all American steam railroads.

3. The number of suburban passenger trains is approximately one-half the number of such trains at present operated electrically on all American steam railroads.

4. The passenger train miles in through and in suburban service in Chicago amount to 70 per cent of the total number of passenger train miles operated electrically on all American steam railroads; the total passenger car miles are, however, greater for the Chicago terminal.

5. Freight traffic, exclusive of switching service, is ten times greater in Chicago than on all existing electrified steam railroads in America.

6. Switching service in Chicago is sixty-five times greater than on all existing electrified steam railroads in America.

7. The number of multiple-unit cars required to operate the Chicago service amount to 66 per cent of the total number of such cars in service on all American electrified steam railroads.

8. The number of electric locomotives required for the Chicago service is approximately four times the number now in service on all American electrified steam railroads, and is approximately two and one-half times the number now in service on all electrified steam railroads in the entire world.

These statements of fact can not fail to give a measure of the size of the Chicago problem. It is equivalent to undertaking at a single stroke an electric installation greater than all steam railroad electrifications in the entire world.

The committee made no pretense at choosing a system of electrification, but it worked out its estimates of cost for each of three systems as follows:

1. Third rail, 600 volt, direct current.
2. Overhead contact, 2,400 volt, direct current.
3. Overhead contact, 11,000 volt, alternating current.

In making up these estimates of cost the committee assumed

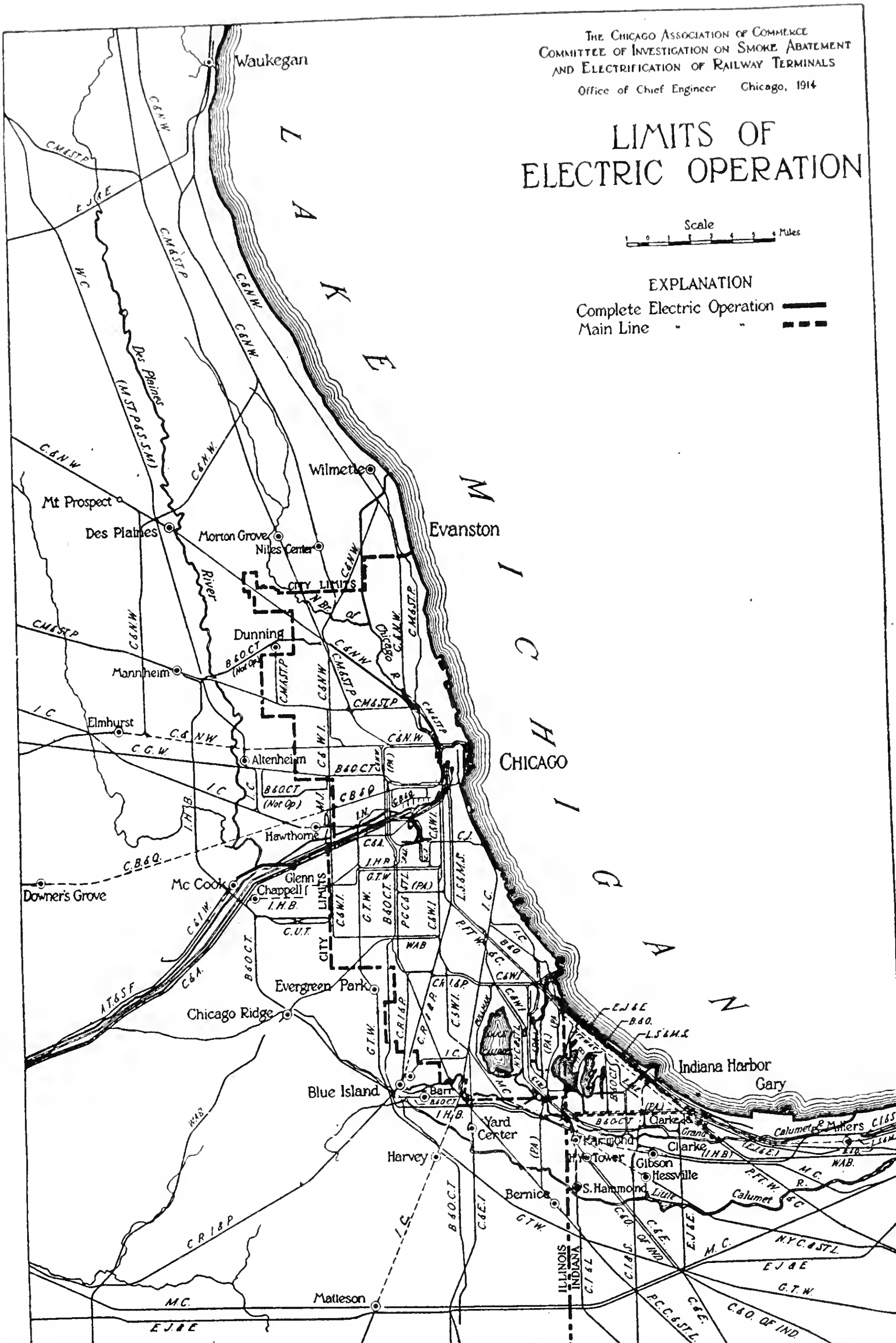


Fig. 14. Trackage to be Electrified in the Chicago Railroad Terminals.

that if electrification is entered upon in Chicago, it will be undertaken as one great problem. Consequently, instead of thirty-seven different railroads building thirty-seven different power stations, there will be one or perhaps two power houses to supply all of the energy necessary for the electric operation of all roads. Similarly for the transmission system, it is assumed that the energy will be transmitted by such a system as will be must efficient in reaching all of the railroads, irrespective of the location of individual lines. The same applies also to the arrangement of substations, switching stations, telephone systems, etc. The estimates are based upon plans designed to meet the requirements of the terminal as a whole.

Estimates of the cost of electrification have been made up item by item, the larger subdivisions being as follows:

1. Power station.
2. Transmission system.
3. Substations.
4. Switching stations.
5. Overhead contact system.
6. Bridge warnings.
7. Prevention of inductive effects and electrolysis.
8. Return circuit.
9. Telephone system.
10. Electric locomotives, multiple-unit equipment, work inspection equipment.
11. Spare parts.
12. Alterations to bridges and buildings.
13. Changes in wire lines.
14. Changes in signal systems.
15. Removal and re-establishment of steam locomotive terminals.
16. Rolling equipment released.

The total estimated cost of electrification for the 11,000 volt A. C. system was found to be approximately $188,000,000. By deducting from this the salvage from facilities to be abandoned or utilized for other purposes and the salvage value of rolling equipment to be released, the net cost of electrification by the 11,000-volt A. C. system is reduced to $178,000,000. It must be remembered, however, that this figure represents the cost on the basis of the committee's plan which is to be regarded as a minimum plan. It does not cover the cost of improvements which would be precipitated by the proposition to electrify. For instance, the railroads of Chicago have spent large sums of money in elevating their tracks, and the whole scheme of track elevation is not yet finished. A railroad would not feel that it could afford to place the facilities and structures of electrification at the present grade if within the next ten or twelve years it would be called upon to raise that grade. It would be compelled, as a preliminary to electrification, to make the remaining improvements for track elevation. These improvements,

of course, would ultimately have to be made, and the charge to cover them is not a charge against electrification, but the adoption of electrification would bring them forward, and by so doing would increase the capital requirement incident to electrification. Again, in the case of signals, which in the event of electrification would need to be rebuilt to permit of their operation in the presence of propulsion currents, many railroads would regard it as good business to make at this time complete installation of new signals rather than spend money in the repair of old signals which might, within eight or ten years, be renewed in any event. This cost of new signals would, therefore, be precipitated as a result of the proposal to electrify, although it could not, of course, be included as an item chargeable to electrification. It has been estimated that the total cost of betterments which will be precipitated by electrification will amount to $96,000,000, bringing the total capital requirement for the 11,000-volt alternating current installation to a total of $274,-000,000.

Let us consider now just what the railroads might expect to get from their investment of $274,000,000. The changes in operating conditions, which will result from complete electrification, are of a threefold character:

1. Those incident to the introduction of electric operation on trackage within the proposed limits of electrification as defined by roads.

2. Those incident to the operation of transfer stations at which change of motive power is to be made.

3. Those resulting from the shortening of the steam-operated divisions at present terminating in Chicago.

These changes will introduce changes in operating expenses, the nature and extent of which will be influenced by the character of the electric installation. The committee found, after a careful study in which each operating account was considered separately, that the electric operation of the Chicago railroad terminals would result in a reduction in operating expenses on the electrified trackage of $3,700,000 per annum under the 11,000-volt A. C. system; that the additional operating expenses incident to the new transfer stations required would amount to $1,500,000 per annum; and that the additional constructive mileage to steam locomotive crews due to the shortening of the steam-operated divisions would cause an addition to operating expenses of $450,000 per annum. By combining these three totals it will be noted that the net decrease in operating expenses, which will result from the introduction of electric operation, will amount to approximately $1,760,000 per annum. It must be remembered, however, that this estimate does not include any amount to cover interest or depreciation on the proposed new electric establishment. The railroads will have to provide capital for the electric installation, and the interest on this capital will amount to $8,900,000 per annum. Depreciation on the new estab-

lishment will amount to $7,800,000 per annum, and the railroads will have to replace assets dissipated by the introduction of electric operation to the amount of $2,300,000. If this item of dissipated assets is spread over a period of ten years following the completion of the electric installation, the charge will be $230,000 per annum. The total of these three items amounts to nearly $17,000,000. After credit is taken for the estimated increase in net revenues, the annual deficit still remaining will be about $14,500,000.

It is obvious from these facts that if we view electrification purely as an investment, the railroads would find it impossible to furnish the necessary capital for the project.

If we go a step further and consider whether there is any way by which the railroads might get the $14,600,000 annually required to sustain the investment, we will see that the electric installation will give some increase in track capacity, especially in the case of tracks used for suburban service; that there is a possibility of extending electric service to provide additional returns to the railroads; and that there will be some reduction in noise and smoke. The extent to which electrification will serve to reduce smoke is the matter in which we are most interested, since electrification has been proposed solely as a means in smoke abatement.

Smoke has been defined by the committee under these heads:

1. Visible Smoke.
2. Solid Constituents of Smoke.
3. Gaseous Constituents of Smoke.

It has been shown that the elimination of all the steam locomotives of Chicago would reduce the visible smoke or the cloud effects of smoke by about 22 per cent. It has also been shown that the introduction of the new power plant necessary to electrification, or the increase in the capacity of existing power plants, would introduce a new source of smoke amounting to about 2 per cent, so that the net reduction in visible smoke through electrification would be about 20 per cent.

The solids of smoke which include the dust and dirt emitted from smokestacks would be reduced through the elimination of the steam locomotive by about 7½ per cent, and there would be introduced through the operation of the new electric power station something over 2 per cent, so that the net reduction would be about 5 per cent.

The gaseous products of combustion would be similarly affected, and the net reduction would be about 5 per cent.

The effect of electrification upon the safety of the public and of employes would be very slight.

It has been suggested that it might be possible to increase the return to the railroads through the more intensive use of railroad property, such as by building structures above the railroad right-of-way. The committee calls attention to the limitations which would apply to such practice. First, there are only land values which

could be realized upon. A building built above the railroad would itself represent a certain investment which would have to be carried. The only gain would lie in the land value, and it would be only in locations where the land adjacent to the property is of high value that any considerable return might be obtained through this sort of intensive use of railroad property. The cost of constructing foundations for buildings over railroad right-of-way would also be considerably greater than in the case of buildings where provision for the track and track facilities did not have to be made. Second, property, obtained by railroads by right of eminent domain is not free for commercial uses by the railroad company. The abutting property owners retain rights in the property which would preclude such intensive use. While it would be possible for a railroad company to build a two-deck station or an office building for its own use above its tracks, it would not be possible for it to erect on land which it had obtained through right of eminent domain, a building for general commercial purposes to be used as a source of income. The conclusion of the committee is, therefore, that while there are possibilities of gain through intensive use of property, a limit to the gains which are possible is soon reached.

When we count the costs and give consideration to the rather indefinite character of the possible returns, it is quite evident that the proposal to electrify the Chicago railroad terminals presents many serious difficulties. The committee's conclusions are to the effect that while it would be technically feasible to electrify the entire railroad terminal of Chicago, the proposal under present-day conditions is financially impracticable.

Discussion.

E. C. Carter, M. W. S. E.: What percentage of the total pollution is due to the steam railways?

Dr. Goss: Atmospheric pollution?

Mr. Carter: Yes, sir,

Dr. Goss: In the visible smoke, about twenty per cent.

E. H. Lee, M. W. S. E.: What would you say is an average of the three, the visible smoke, the solid constituents, and the gaseous?

Dr. Goss: The committee spent a great deal of time in its effort to get a simple expression for pollution, an expression which would combine the visible effects with the dust effects and the gaseous effects, but there is no relation between these different manifestations of smoke. The smoke from a stack may be invisible and hence non-existing, apparently, as far as the eye is concerned, but it may be a very serious source of dust pollution; and the committee's conclusion is that the thing which Chicago most complains of in its atmospheric pollution is the dust and the dirt in the atmosphere, rather than the cloud effects. Now, it is a fact that we have all through this loop region of the city fires which are burning under high pressure steam boilers, which are stimulated to rates of

combustion equal to and in excess of the rates of combustion which are the average rates in locomotive service, and the dust discharges per pound of coal burned from these stacks is as great as the discharges from the locomotive fires; so that the amount of dust discharged from fires other than locomotive service is very great. But that is another story. That is the story of the smoke and the atmospheric pollution, and I have not attempted to tell that story tonight.

Mr. Carter: There would then continue to be 95 per cent of the dust pollution that would still continue to exist after the steam railways had been electrified?

Dr. Goss: Practically so.

Mr. Carter: So the cost of electrification would then remedy only five per cent of the most pernicious feature of air pollution?

Dr. Goss: It would only remove about 5 per cent of the dust and dirt of the atmosphere.

Mr. Lee: It is a fair assumption, it is not without pinning the committee down to accurate expression, that it was the general feeling that the last two items were of more importance in their general effect than the first, visible smoke?

Dr. Goss: That was, I think, the opinion of the committee.

J. R. Bibbins: In regard to the estimated growth in steam traffic from the present time up to the year 1922, it would be of great interest to know if any new law of growth has developed from the studies, more definite than an arbitrarily chosen decreasing rate of increase, *i. e.,* any functional law expressing the relation between the growth of traffic and population respectively.

Dr. Goss: Yes; an equation was written—I suppose an equation always represents a law—and it is a diminishing rate for certain of the factors, not for trackage. Trackage is a straight line equation.

Mr Bibbins: I assume that. I had occasion recently to compile some statistics for the United States, as to the increase in traffic using for convenience a logarithmic chart. The results are concisely stated in the following extract from "Report on Railroad Terminals, City of Chicago," by Bion J. Arnold, December, 1913:

"Taking the country as a whole, the population of the United States has increased since 1870 at an average rate of 24 per cent per decade. In accordance with the known law of normal growth, the rate of increase has become less and less during the succeeding decades, *e. g.*, 30 per cent from 1870 to 1880, and 21 per cent from 1900 to 1910.

"The north central states, principally comprising Ohio, Minnesota, Indiana, Michigan, Wisconsin and including the City of Chicago, have shown an *almost constant increment* of population in each decade of the last forty years.

"The results for the country as a whole, and the north central states in particular, indicate that the underlying growth of population is generally consistent and constitutes a reasonably sound basis of

prediction for Chicago, whose traffic is unusually representative of the country as a whole.

"Due to its geographical position Chicago has become the most important transfer point of the country; consequently, its train traffic, especially for through trains, will be influenced largely by the growth of the country as a whole rather than by the growth of the city. On the other hand, suburban traffic will depend entirely upon the growth of the Chicago district, including distant suburbs.

"*Train Mileage.* A consistent increase in train mileage operated in the United States occurred from 1890 to 1910 (with the exception of the period of financial depression from 1893 to 1896). Neglecting the effect of this depression a statistical analysis of the available data shows the remarkable fact that:

"Train mileage of the United States has increased within the past two decades approximately as the *square* of the increase in population, *i. e.,* as the population doubled the operated mileage has quadrupled.

"The above law may be regarded as expressing normal growth only during fairly prosperous times, since the effect of abnormal influences, such as continued financial depression, cannot be foreseen or estimated.

"Applying the same analysis to the north central group of states surrounding the Chicago district, it appears that the train mileage operated has increased *at least* as the square of the increase in population of these states, which corresponds approximately with that of the tributary population along the lines investigated.

"Since train mileage will be nearly proportional to trains operated, the above figures for increase in mileage represent approximately a measure of the increase in train handling capacity in and out of Chicago which must be provided for in computing the future station capacity required. This assumption is more or less borne out by the fact that there was from 30 to 35 per cent increase in trains operated in and out of Chicago for the last decade (1900 to 1910). For the whole country train mileage increased 50 per cent and for the north central states 40 per cent.

"A similar analysis of the records of passenger traffic indicates that for the entire United States the traffic has been increasing approximately as the *cube* of the increase in population (neglecting the depression of 1893 to 1895).

"For the north central states it appears that the passenger traffic is increasing at about the same rate as the entire country."

Judge Jesse Holdom: There is very little to be said after Dr. Goss' lucid statement in which he has treated such a very, very large subject in such a comparatively short time. I know there is not a word I could add that would give you the slightest information that has not been conveyed to you by Dr. Goss. Therefore, I will not attempt to inflict upon you any remarks of my own. However, so much talk has been indulged regarding smoke and air pollution

created by the railroads that I will venture one observation. I think it is not betraying any confidence when I say that the deductions which the committee has been able to make from the exhaustive examination they have given the subject is this: That if all the railroads of Chicago were electrified and there was not a smoky or coal locomotive allowed to come into the city, the decrease in the visible effects of smoke and air pollution would be so little as to be negligible. Let me add that the success of the committee's labors has been largely possible by the leadership of its chief engineer.

C. L. Dering: There is just one thought I wish could be made clear tonight, and I do not know whether you got it with distinctness from what Dr. Goss has said.

The newspaper criticism against the committee work about this problem has been directed to the statement that the committee did not consider electrification in part or the electrification of suburban terminals, if you please, or the electrification of the terminals of one suburban railroad. I trust that you understood clearly from Dr. Goss' statement that that was not what the committee were asked to consider. That was not the problem before them at all.

Peter Junkersfeld, M. W. S. E.: Mr. Dering has stated very clearly one of the facts that it is necessary to keep in mind, and that is the problem or the question that was asked the committee, namely, electrification as a whole. If the question has been asked in a different way, it is quite possible there would have been an absolutely different answer. As the question was asked, the committee had to consider the average air pollution over two hundred or more square miles, and the average of cost over some thirty-four hundred miles of track. The air pollution in territories containing more densely operated tracks or more densely operated group terminals, would, of course, have a very much higher percentage of pollution than the average of the total trackage. Likewise, the question of cost, if applied only to the more densely operated railroads or group terminals, rather than to the average, that also would have produced a very different answer. But, as has been said before, that was not the question that was put up to the committee.

President Jackson: I am sure that one of the thoughts that probably came to Mr. Junkersfeld when he saw the average hours, average killowatt hours, was the thought that all of the railroads apparently might be operated from one good, big steam turbine generator.

A. Bement: A few questions occur to me regarding matters which have attracted my attention, and I will present those questions for my own information.

According to the table we have been shown by Dr. Goss, it appears that by 1922, when the assumed electrification would be completed, there would be 5,000 miles of track. I would ask if in arriving at this estimate any allowance has been made for the effect

on car movements of the operation of the transfer yard at Clearing, and if the influence of the proposed scheme for handling L. C. L. freight which is now being developed with terminal at Clearing, has been taken into consideration as affecting the amount of trackage required in the future.

In the list of railroad electrification given, I would ask if the Norfolk & Western and the Chicago, Milwaukee & St. Paul have been included.

I would ask why it was considered necessary to include a powerhouse as one of the items of cost of electrification at Chicago.

Elmer T. Howson, M. W. S. E.: I am sure we all feel that Dr. Goss has covered this subject so thoroughly that we at least have a very excellent general impression of the magnitude of the problem of electrifying the steam railways of Chicago. When we realize, as he has pointed out, that the mileage which it has been proposed to electrify is greater than the total electrified steam mileage of the world, we gain some idea of the problem confronting the people of Chicago.

I have been thinking of the expenditures the railways have made, are now making, and would be called on to make for this electrification. The railways have already spent over $80,000,000 for track elevation and this work will cost $70,000,000 more, or a total of $150,000,000 before its completion. They have spent and are planning to spend a total of perhaps $150,000,000 for passenger terminals. Add to this the cost of electrification, and we have from $475,000,000 to $575,000,000, depending on the electrification estimate used, all spent within the radius of 25 miles of Chicago and primarily for the benefit of the Chicago public. If we divide that amount by the total mileage of all the railways entering Chicago, about 80,000 miles, it represents an expenditure of between $6,000 and $7,000 per mile of line for every mile of every road coming into Chicago, or nearly 15 per cent of the present capitalization of all these systems for one local terminal.

If we turn to the question of operating expense, the commission's figures show an increased annual operating expense of approximately $14,000,000. It was only last week that the Interstate Commerce Commission granted the western railroads an increase in passenger rates, believing that the present revenues were not sufficient. This commission has also granted certain small increases in freight rates on the same basis. If $14,000,000 is added to the cost of operation for one local terminal, the Interstate Commerce Commission evidently has still another problem confronting it in determining adequate rates.

The question of the best electrical system is one of a great deal of debate at the present time. There are the various electrical systems, each with strong advocates. There are many problems still to be worked out with each of them. I thought of that a few days ago when I learned of the effect of the storm of last week on

the New Haven road. The electrified system between New Haven and New York was entirely out of service for electrical operation for two entire days. The effect of that will be realized fully by railway men. They had to go back to steam locomotives to get the line into service. It simply shows not that electrification is not practical, but that there are still some problems to be solved before we tackle a situation as complicated as Chicago.

President Jackson: Mr. Howson's remarks bring up one of the features of this problem which I brought before the original electrification committee. I was heartily in accord with the report of the original electrification committee, with the exception that I felt it should have gone a step further, which was to the effect that there should be worked out some plan by which, in the case of an improvement, such as the electrification of the railroads in a city like Chicago, a reasonable portion of the cost should be borne by the people of the city since the improvement would be made primarily for the comfort of the people without proportionate increase in the net income of the railroads.

I am inclined to think that something of that kind should still be done, because I am convinced that if we can eliminate the smoke of the locomotives in Chicago, we will have an improvement of very much more than twenty per cent in our apparent cleanness of atmosphere. At the time of the original report, it was fairly well appreciated, at least by some of us, that the working out of the problem meant the matter of the expenditure of a couple of hundred million dollars. That is about the figure that we had in our minds, and that seemed the feature of the problem. It also seemed to me that there is no reason why a city should not work out some plan whereby it will assist in an improvement which means a real help to the city in cleanliness, in quietness, and in many other ways, and I am inclined to think that possibly one of these days we shall come to that. I do not see any valid reason why we should not help to take care of an improvement that would be of such unquestioned value to our city, why we should not help to push this improvement just as we do the improvement of the streets in the city. Every year we permit the plan to lie dormant means that the difficulty of getting the improvement well started is increased. Such being the case, why is it not up to the citizens of Chicago to face a problem of this kind squarely, and say, "We need this electrification and it is up to us to see to it that we work out a fair plan by which we can get it?" But when we come to the problem, first, as Mr. Howson has said, of throwing upon the railroads over a hundred millions of cost for track elevation, which now some people say was all wrong; and then throw upon them again this load, which, as Mr. Howson has said—I have not figured it out, but his figures are usually correct—would add $6,000 per mile of the trackage of the roads coming into the city, it really seems like adding a very extraordinary burden. But it would not be unreasonable for the City of Chicago

to help finance such a problem along some well-developed plan. That problem requires solution by some able commission that would handle it in a broad way as to its effect upon the railways and upon the city.

Mr. Lee: Dr. Goss has given the information, but the point is this: Here is five per cent of the actual pollution of the Chicago atmosphere produced by locomotives. The only tangible reason for spending $15,000,000 is to eliminate this 5 per cent, barring certain specific advantages for certain particular areas. Now, if it cost at the same rate to eliminate all the atmospheric pollution, it would cost $300,000,000 a year. That is a figure, I think, shown in the report, or it is brought out in a statement bearing on the report that I have heard. It is also a fact, and I think it is made clear in the report, that certain agencies that produce smoke and pollution of the atmosphere could be corrected at enormously less cost, cent per cent, than this five per cent that the railroads produce through their locomotives. If that is true, why isn't it good business for the City of Chicago to make an attack along the line of least resistance?

Albert Reichmann, M. W. S. E.: To oppose the electrification of the Chicago terminals would be non-progressive, which trait, in America, is thoroughly despised by all. If our statutes could be so modified, I think it would be perfectly proper to electrify such suburban lines as the Illinois Central, and possibly others, providing the property in the vicinity could be taxed, in proportion to the benefits which would accrue to it, for at least a greater part of the expense of electrification.

You said a little while ago that it would be all right for the public to pay for the electrification of the terminals. I must say that I am very much opposed to this. Assuming the population of Chicago to be about two million people; if the interest charges were to be paid by the citizens of Chicago in the form of taxes, it would mean that each citizen would be compelled to pay an additional tax of about $7 a year, based on the figures quoted by the author. In other words, for an average family of five, it would mean an increased annual tax of $35.00, or approximately $3.00 per month. This is as much as the average man spends for carfare. The burden of this additional taxation would certainly be very objectionable to the great mass of the people. I believe that if we made a careful analysis of many improvements and found out to what extent they would tax our own purses, we would have a clearer idea as to whether or not we wished to have the improvements made.

I have been considering the subject along the lines Mr. Howson has been talking about, and to give a fair idea how some of these extensive public improvements affect the capitalization of the railroad properties, wish to state that while talking wih a friend of mine about the new Union depot in Chicago, we figured that it would cost one of the railroads entering into this project about $2,000 per mile of its mileage, which would mean that the railroad would have

to earn about $100 additional a year per mile of road to pay its share of interest in this terminal.

The question of spending money lavishly for terminal improvements must be given the most careful consideration by our railroads or else our railway capitalization will be so great that in order to earn their fixed charges the railroads must necessarily very materially increase their freight and passenger rates, which would be a very decided disadvantage to the American people, inasmuch as the average haul of our products is four to six times that of European countries. Furthermore, the large amount of products exported by the United States is of the more crude form and in order to be able to export many of these articles it is necessary to have low freight rates.

I believe that the higher cost of transportation on the European railroads is due largely to the vast amount of money which the Europeans spend upon their terminals. Inasmuch as their cities are much closer together than ours, the capitalization consequently becomes very much increased per mile of road. As a consequence, their fixed charges are higher, and both freight and passenger rates must be higher.

President Jackson: I ought to add, in connection with my remarks, that it was not proposed by the original committee that we would electrify Chicago over night, but it was thought that it would be very desirable and very advantageous to start business. That is the thought that I want to get at; that as we wait it means just so much more difficulty in starting. Exactly the same as in our city plan, for every year that we wait it means so much more difficulty in ever getting a suitable plan started.

Wilson E. Symons, M. W. S. E.: I do not know that there is anything I could say that would add to the value of this very interesting lecture and the discussions. I am quite sure there is not.

There are one or two thoughts, however, that have occurred to me in connection with the report recently issued on this subject. The volume spoken of by Professor Goss in his address may be considered a standard text-book or monograph on the questions treated. It is not only the last word on the subjects treated, but will be of great value in years to come. It is useful now in many ways, and the fact that it has required quite a number of years for its compilation has been very beneficial to the City of Chicago and the railways. It is only a few years ago there was the general agitation with reference to smoke pollution of the air in Chicago that has been spoken of. The public mind was systematically poisoned on this subject, particularly against corporate interests. Almost every one who thought of the matter could see the smoke coming from locomotives, but did not see much coming from stationary chimneys. There was constant talk of, and a demand for immediate legislation to force the railroads to electrify at once.

It is very fortunate, indeed, that this study has been made by

men of reputation, who are authority on these subjects, so that the way is now clear how we can best proceed in the matter.

We always feel gratified when we are endorsed or agreed with by men of prominence; inversely, we feel keenly the disappointmnt when we are disagreed with or criticised by people of equal prominence. When this agitation of the smoke problem was first brought up some years ago, I ventured the assertion from the floor of this association, that, as the railways were consuming only about 18 per cent of the coal in the city, they were responsible for only about 18 per cent of the smoke emitted. Men of prominence said that 18 per cent of coal produced 43 per cent of the smoke. I felt rather badly over our inability to get closer together, but felt the error was greater in my opponents' calculations than in mine, and am much gratified to find from this report that I was nearer right than the gentlemen who disagreed with me.

I am very glad indeed that this report has in substance endorsed my first estimate of 18 per cent of smoke chargeable to locomotives, and also a later one in which I expressed the belief it was less than 18 per cent.

Again, it was asserted on the floor of this association that the Illinois Central Railway could electrify its terminals for four million dollars (less cost of powerhouse) and again I disagreed. I said—I had not an opportunity at that time to make an estimate—but it was my belief that if twice four millions were provided, the work would not be well under way until another four millions would be necessary, and that in the end it would be found that twelve millions would not be sufficient. I see by the figures in this very able report that it will cost more than twenty millions. I felt sure at the time that it would cost fully twenty millions, but that a figure of twelve millions was more conservative, and this low estimate was three times the estimate I criticised. I am gratified to know that I am again more than endorsed in the matter of cost to electrify the Illinois Central Terminals.

With reference to the feature mentioned by one of the previous speakers in connection with the New Haven, I think that incident serves as an additional reason why we may consider ourselves fortunate in Chicago, no matter whether we be railway men or just plain citizen taxpayers, that this investigation has been so thoroughly made, and that it required considerable time to make it, for the reason that the electrification of steam railways was *largely an experiment,* and is yet, to some *extent,* in the experimental field.

In the agitation some years ago for immediate electrification, reference was made to the roads that had electrified, and among those mentioned the New Haven was one of the most prominent. Quite recently Mr. Murray, an electrical engineer who installed the New Haven plant and now has charge of it, and who is, of course, an authority on electrification, has spoken with reference to their experiences. He has been very emphatic in what he has said, and

for fear I may misquote him, I will just read extracts from his address before the Franklin Institute of Philadelphia, Pa., this year.

First: In the matter of costs, he says that in the light of ten years of experience their installations have probably cost them about forty per cent more than they would if they were now in a position to commence anew and do their work over again, and that better results could be secured.

Second: In the matter of the experimental features, he is very plain. He says:

> "Some road had to make the first break into the dark. No one had any advice to give, as *no one* had any experience upon which to base it."

Remember, gentlemen, this statement refers to a period of time when the politicians and press of Chicago were clamoring for *immediate* electrification of steam railways.

> "Some of our critics have been inclined to view the New Haven electrification as a *great experiment*. They are *right*—it *was;* but as an experiment it has given a cleaner and more reliable ride for the public, and in the end will not cost the New Haven a (economic) penny; but its greatest value, in my estimation, has not been so much this as the more stable position in which it has placed the other roads of the country to consider electrification, a subject to which they will have to address themselves in the *near future.*
>
> "The larger part of the experimentation is over."

I want to emphasize that particular point upon the minds of my readers, that in 1915 Mr. Murray, an authority on the subject, says that the *larger part* of the experimentation is over.

> "And from the data assembled, future results, in the application of electricity in heavy trunk line territory, can be predicted on assembled facts, and not predicted from hypothetical analyses. Critics have had it that the so-called 'battle of systems' has delayed the electrification of railroads. As an electrical engineer, keenly alive to the desirability of interesting railroads in moving their trains by electricity, I am glad if any insistence upon my part upon the matter of 'system first' has delayed electrification in this country, and argue that *every minute* of the delay will be a *future asset* to the railroads."

Gentlemen, I submit the quotations from Murray's lecture before the Franklin Institute as being in harmony with the views of the Chicago committee of which Professor Goss, the speaker of the evening, was chief engineer.

The fair-minded people of this city should feel grateful to this committee for the splendid results of their labors, which seems to me to be the last word in cause, effect and remedy in pollution of atmosphere and electrification of steam railways.

From the editorial on page 1179 *Railway Age Gazette* of Dec.

24th it would appear that the New Haven's electrified zone is still, to a considerable degree, in the experimental field, particularly in the matter of dependability under adverse weather conditions.

This should serve as a warning to those who seek to force the railways, by legal process, to undue haste in the disposition of a matter involving the expenditure of many millions of dollars, and is one of the most important factors in commercial life of a city of two and one-half million people.

James N. Hatch, M. W. S. E.: I would like to ask a question which the committee apparently thought it was not a part of their province to answer, but a question I have asked a good many people and for which I have never received a satisfactory reply. It seems to me that all I have heard of smoke abatement in Chicago presupposes electrification to be the only method worth considering to effect the result. It has often come to my mind why the railroads have not interested themselves, or why they could not be interested in abating their smoke nuisance without electrification. I have often wondered why they did not adopt something besides soft coal for burning in their locomotives inside the city limits. My question has never received any answer that was satisfactory to me and I would presume that Professor Goss incidentally might have gotten some ideas on the question which might be of interest to us at this time.

J. W. Lowell, Jr., ASSOC. W. S. E.: As I remember, the amount of total expenditure was placed at about $187,000,000, including precipitated costs, that is, track elevation, bridges, rebuilding, signals, etc., incidental to electrification. Now, I wish to know, how much of the $187,000,000 is precipitated cost.

Dr. Goss' investigation convinces me that the expense of electrification from a standpoint of investment is at present undesirable, but I fully believe that some day a change from steam to electric operation inside the limits of Chicago will be realized. Therefore, some progressive plan which would distribute the precipitated expense over a term of years, by making all railroad improvements in accord to such plan, will make ultimate electrification more satisfactory and less expensive to all parties concerned.

Dr. Goss: The $178,000,000 does not include any of the precipitated cost, and the balance sheet, the annual balance sheet, does not include them at all. They are regarded for the purpose of the balance sheet as undetermined. So the balance sheet is based upon the actual expenditures for electrification, and while I am speaking of that, I will refer to Mr. Bement's questions, all three of which are very pertinent.

Of course, it is conceivable that this whole railroad establishment of Chicago might be unscrambled and a new establishment put down, which would support new operating procedure and be a very much more efficient proposition than that which we have today. But it would be a great task to accomplish that, and it was not

within the province of our committee to study that question. There is a commission in Chicago which is studying certain phases of that subject, the terminal aspects of it, and our committee did not think it wise to go into it at all. Consequently, our full procedure has been based upon the establishment as it existed in the year 1912. The proposition was: Electrification must come; it must come on trackage that we now have; it must accommodate the operations which we now have. What will it cost? That was the proposition the way it came to us.

Concerning the reduction of smoke, certain questions have been asked, and the questions which have been asked have stimulated me to respond to some which have not been asked. This whole story, to be told right, should begin with the story of the sources of smoke, smoke suppression, and the real responsibility for smoke from different services; but that is a story in itself. It would have taken me an evening to tell it, and I thought you would be more interested in the electrification story than in the smoke story. Consequently, I have left the smoke story out, but I am going to touch upon it at one or two vital points in order that I may answer the questions that have been asked.

First, as to the possibility of reducing smoke from locomotives. You may not all appreciate the fact that the railroads of Chicago have done and are today doing a great work in reducing locomotive smoke. The fact is that the locomotives of Chicago, as compared with the same locomotives outside of Chicago, where there is no inspection and where there is no urgency to reduce smoke, are giving only about half the normal amount of smoke. This condition is due largely to the inspection which today is being generously sustained by the railroads themselves. You may not know that the railroads of Chicago have a larger staff of smoke inspectors working on their own locomotives and watching their own men than has the City of Chicago.

It has been suggested that perhaps by change of fuel it would be possible materially to reduce smoke from locomotives. If we could use anthracite, for example, we would not have so much smoke, and if we could use coke, we would not have so much smoke. There are limitations in the choice of a fuel for locomotive service, and one has to be rather familiar with the service before he can appreciate their extent and character. This much we may be sure of: That any attempt to solve the problem through the choice of fuel will not operate to reduce the dust and dirt from locomotives. Coke fires will be just as dirty and more dusty than soft coal fires; and, after all, as was said in the beginning, it is the dirt that we object to more than the cloud effects.

Our President and others have spoken of the matter of cost. Assuming that we know what it is going to cost annually to operate electrically, how can we provide for it? There were many members of the committee, who were very much interested in that

question. Can't we put an extra cent on each suburban fare; can't we put five cents on every through passenger ticket that is issued; and can't we put ten cents on every ton of freight that is brought into Chicago? An arbitrary charge of that sort will pretty nearly carry the cost of electrification. May we not in some other way give the railroads a chance to earn the money, either by a terminal charge, or by increased rates over the whole line, whereby this improvement can be made?

The conclusions which grew out of the consideration of questions of that sort were to the effect that in whatever way that charge may be applied, it would ultimately come back to the business interests of this city, and the real question becomes in effect: Is the city sufficiently interested in having electrification to bear the cost?

Another aspect of the problem of meeting the cost may be set forth as follows: Electrification will, in a large sense, be a public improvement; that is, it will not only better the railroad service, but it will better conditions in which the public is interested. It is a public benefit to have electrification, and consequently the public would perhaps be willing to pay for it. Why not ask the city to aid by bearing a considerable portion of this expense through a bond issue or by other means? Why not recognize it as a public improvement, just as good streets constitute a public improvement, and let the city pay for it? The answer is not far to seek. The simple fact is that the constitution of the State of Illinois absolutely prohibits any co-operative movement of that sort, and until the state constitution can be amended it will be impossible for any such scheme to be carried out. I merely mention these things to show you that each one of these propositions, which naturally occur to one who thinks about the matter rather carefully, has been considered, and those of you who undertake to become familiar with this 1200-page report will find them therein elaborated.

Questions of cost bring us at once to the question as to what is to be the return on the investment. If we could eliminate all the smoke of the City of Chicago and have a clear atmosphere, a pure country atmosphere, through the electrification of railroads, there would be a strong incentive for this community to tax itself in some way, direct or indirect, in order that this might be accomplished; but the gain is comparatively small, and you can not appreciate that fact until you review the committee's figures more or less in detail. I will refer only to two or three of the facts so that we may have them in mind, not as a definition, but as a partial setting for the definition.

The locomotives of Chicago burn practically two million tons of fuel annually. The total consumption within the committee's area of investigation is 21,000,000 tons of coal—2,000,000 by the locomotives and 19,000,000 by other services.

The high-pressure steam boilers of the area of investigation consume 7,000,000 tons of coal, most of it being Indiana and Illinois

coal, which people commonly refer to as smoky coal. Every block in the business district of Chicago has from five to seven power stacks and many small chimneys, and some of these stacks are lofty and active. The fact is that these power plants in the business district are burning hundreds and thousands of tons of coal, and the smoke, dust and dirt from that consumption are going out all over the city. You see the smoke from the locomotives, but you do not see the dust and the dirt that comes from the stack that discharges 300 feet above the street level. The stack is sometimes used to stimulate a fire that burns fuel at a rate of between 50 and 60 pounds per foot of grate per hour, which is practically the average rate of combustion for the locomotive service within the city limits of Chicago, and the dust and dirt per pound of coal are entirely comparable with that which goes out of the locomotive stack.

If for the purpose of getting pure air we should make an unusual sacrifice; if we should see that the money is provided for electrification which will permit us to deal with the smoke from 2,000,000 tons of coal, what are we going to do about the 7,000,000 tons burned under high-pressure steam boilers? Who do we not go after them? Can we not get a larger result in the reduction of atmospheric pollution by going after the high-pressure steam boiler than we can by going after the locomotive service? That is the question.

President Jackson: What modification would you say if you select your particular electrification, rather than taking the district as a whole, that is, beginning with—I won't say the worst offenders, but those points which are of least resistance.

Dr. Goss: I referred especially to the high-pressure steam boilers, but I must not fail to refer to the domestic fires and the low-pressure boiler fires, that is, the fires under boilers in flats, apartments and small buildings. More than 4,000,000 tons, twice as much as is burned in locomotive service, is burned in such fires—domestic fires, heating fires in buildings, and so forth. They are tremendously objectionable when they burn. Of course, they have a seasonal load, and the fact that they burn only a few months in the year gives them a relative standing as smoke producers, which is low compared to that which they should have during the winter months. The fact is that low-temperature fires are fires that discharge the distillates of fuel; oily, tarry, soot particles go out from these low-temperature fires and not from locomotive fires, and those are the discharges which chiefly soil, deface and give trouble.

The industrial fires of Chicago—the manufacturing fires, the blast furnaces, and the brick kilns—burn more than 4,000,000 tons of coal per annum, twice as much as the locomotive, and yet you know that these are by no means smokeless within the city.

In concentrating our attention, therefore, upon a single service, we deny a fact which has been made very apparent by the committee's study, namely, that everybody is responsible for the smoke of Chicago. It is not the railroads alone. It is not the flat owner

alone. It is not the manufacturer alone, nor the high-pressure steam boiler alone. It is everybody. We are all in the business, and if we are going to make real progress, we will have to go at it as a city problem and tackle it, as the president has suggested, at the point of least resistance.

Moreover, all the dirt in the air of Chicago is not from smoke. The committee believes that about two-thirds of it is of fuel origin. The other one-third arises from the unimproved alleys and streets, from the bare playgrounds, from the handling of building material, from the untidy conditions of back yards and roofs, and from many other sources, so that to get the dirt out of the air, you must do something besides suppress smoke. You must improve the whole scheme of municipal house-cleaning.

While the committee thinks from its investigation that two-thirds of the dirt is of fuel origin, it is not at all convinced that two-thirds of it is in its initial descent from the atmosphere after having been discharged from the stacks, because the products of combustion come down and settle on roofs, in streets, and on sidewalks. They are pulverized. The wind picks them up again and they start on a secondary flight, and many particles go the rounds of the city probably for days, and perhaps weeks. They persist until some effectual cleaning process finally disposes of them. There, again, you see, is the place for municipal house-cleaning to come in.

The committee has recommended that a pure-air commission be appointed, which shall conduct research and have authority over all lines of municipal activity that can in any way affect the purity of atmospheric air. That is the constructive suggestion offered by the committee, and you will see the reason for it in some of the things that I have said.

Mr. Dering has called attention to the fact that this partial electrification, which is urged and which is a very acceptable proposition from the standpoint of progress in the art of transportation, is, if it be regarded as a step in smoke abatement, one of not very much importance. For example, if you electrify all of the suburban service of Chicago, we should feel you were making great progress in electrification, but as an aid in smoke abatement, it would be negligible. The total reduction in the amount of smoke in the atmosphere, due to the elimination of the suburban service as a step to bring about a better atmospheric condition of the whole city, would be absolutely negligible. Less than two per cent of the pollution would be taken out of the air of Chicago by that process.

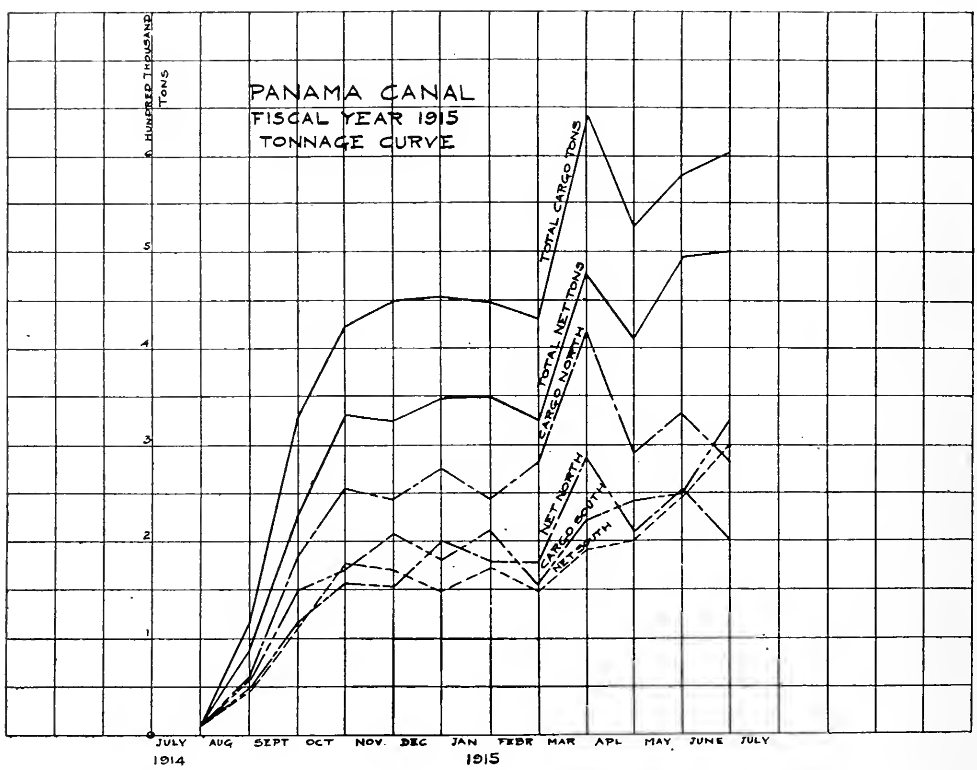
FIRST YEAR'S OPERATION OF THE LOCKS OF THE PANAMA CANAL

By F. C. Clark and R. H. Whitehead

*Presented April 3, 1916.**

On August 15, 1914, the Panama Canal was opened to commerce for vessels having a draft of thirty feet or less. A year has now elapsed, and it is the purpose of this paper to give the results of the experience gained during that time in handling of vessels in the locks.

During the year, 1317 ocean-going vessels were handled in the locks without an accident to them except the occasional breaking of weak chocks (on vessels not locks). The delays to vessels



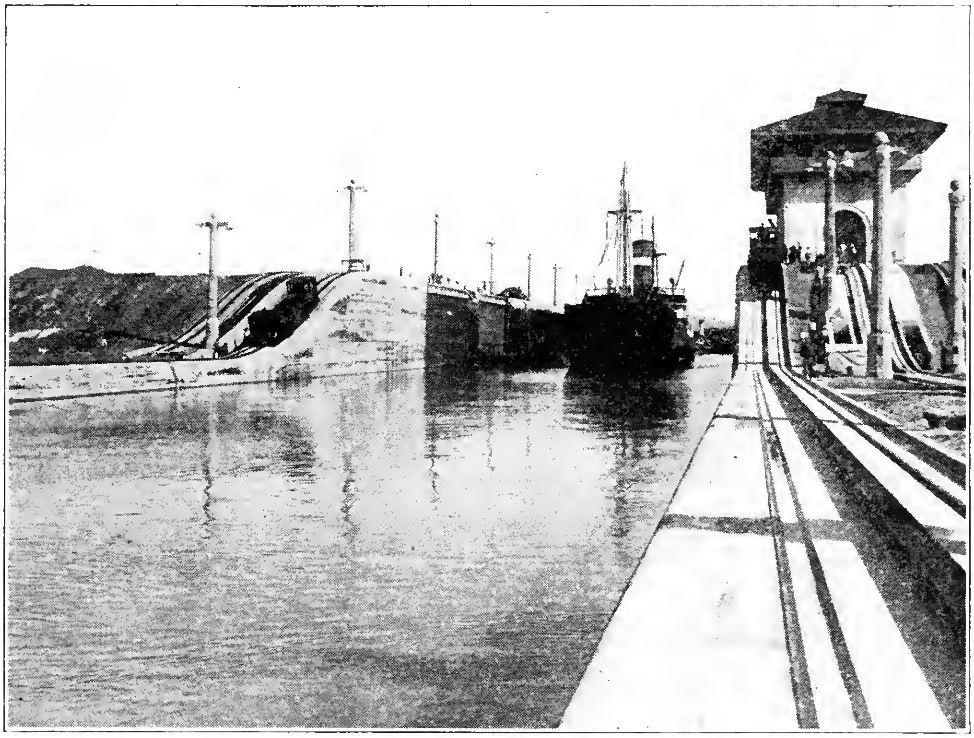
due to temporary failure of lock equipment have not aggregated three hours for all vessels handled, and none of the lock protective devices were called upon to avert a possible accident. Traffic has increased steadily, so that during the month of July, 1915, 170 vessels were passed through the canal.

*Owing to the inability of either of the authors to be present, Mr. S. H. Grauten, who had charge of testing and putting in service of the entire electrical, mechanical and hydraulic equipment at Gatun and operated the Gatun locks for the first nine months, read the paper and answered such questions as came out in the discussion.

Training and Developing of the Operating Force.

The first lockage was the tug Gatun, which was locked up through Gatun locks on September 26, 1913. The locks were watered for the first time on the same day. On October 10, 1913, Gamboa dike was blown up, and from that time on frequent lockages of dredging equipment have been made through all locks. These lockages were made without locomotives until May, 1914, and were handled by the force used to test out the lock machinery. As fast as the towing locomotives arrived on the Isthmus, operators were taken from the construction force and trained.

The first handling of cargo through the canal was begun on May 18, 1914, with the towing of barges loaded with sugar, and this traffic was continued intermittently until August 15, 1914, when



Operation of Miraflores Locks. S. S. Santa Clara Leaving Upper West Chamber, Under Tow of Electric Locomotives. Looking north. June 19, 1914

the regular commercial traffic of through ships began. The handling of the barges mentioned, in addition to the dredging equipment, resulted in frequent lockages and the proper training of the force to handle commercial vessels.

The first commercial vessel through Gatun Locks was the S. S. Allianca, on June 8, 1914; and through the Pacific locks, the S. S. Santa Clara, on June 18, 1914. On August 3, 1914, the S. S. Cristobal made a trial trip from ocean to ocean.

About this time considerable discussion arose concerning the towing locomotives. It was in many quarters thought that two

miles per hour was too fast to handle a vessel having a displacement of 18,000 tons, such as the Cristobal. It was then decided that the ship should be placed under the direction of a lock pilot, who would have authority to use the ships' engines as an aid to the locomotives. Several of the Panama Railroad ships were then locked through under this arrangement, and the plan was finally permanently adopted. From time to time the canal and lock pilots have been interchanged, so that now a large number of the canal pilots lock through their own ships.

At first only a single shift covering a ten-hour day was used on the locks. Since the first night lockage, on December 7, 1914,

Pedro Miguel Locks at Night

when the S. S. Limari was locked through the Pacific locks, a double shift has been working at all locks, and the passage of vessels at night has been a regular thing. The illumination of the locks has been found very satisfactory, and vessels are handled at night with the same rapidity and safeness as in the day time; in fact, the night flash-light signals which are used are, in some respects, more satisfactory than the day signals.

The captains of the ships have been very much impressed with the quietness and smoothness of the operations. The lock machinery is all concealed from view, and practically no noise can be heard from the vessels. The locomotives are handled exclusively by signals. The operating force is in direct communication with the

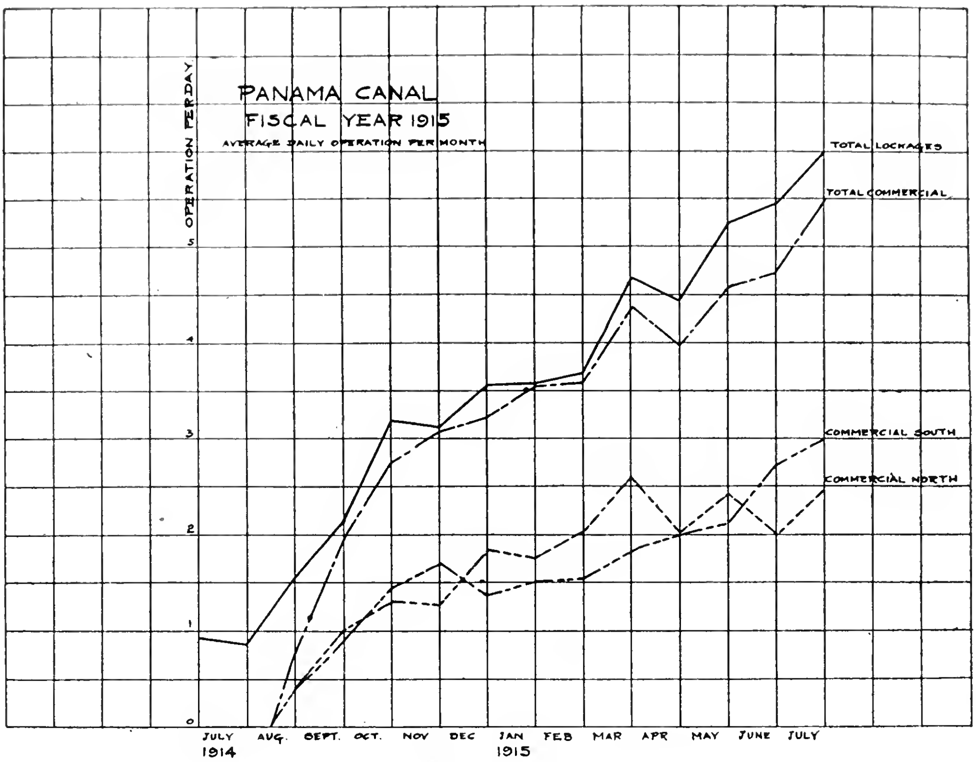


Chart No. 1

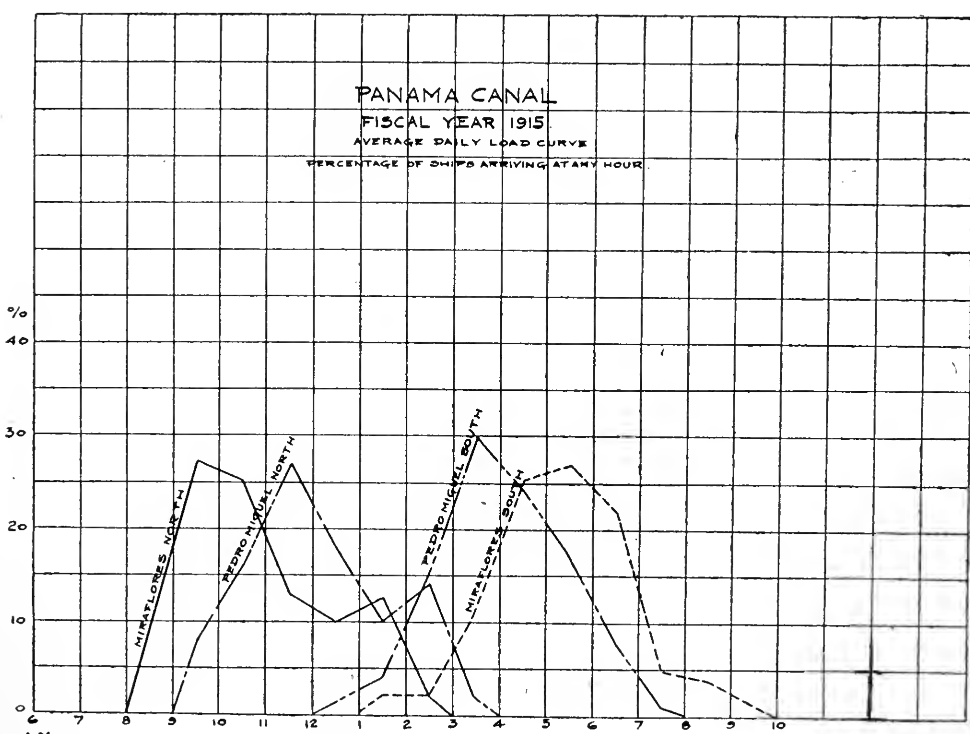


Chart No. 2

control house by a telephone system, with connections at every lamp standard on the walls, and at convenient points in the operating tunnels.

The increase in the traffic through the canal, and consequently the increase in work at the locks, is indicated by chart No. 1. The average day's work for the month of July, 1915, is indicated by chart No. 2. The average day's work for other months follows the general line of these curves very closely, as fundamental conditions do not vary widely.

The change from construction to operating was not an abrupt step, but was a process of evolution. Trained operators were, of course, not immediately available, and men from the construction ranks were tried out, the most apt and efficient being finally rated as operators.

The unit in the organization is a shift, under the direction of one man. The shift is comprised of locomotive operators, tunnel operators and line gang. The tunnel operators, as well as the head of the shift, are in telephone communication with the control house. A shift is composed of fifteen gold men and forty-five silver men.

The emergency dams are now operated with as much smoothness as the lock machinery. By means of various improvements made by the operating force, these dams can be completely placed in position in thirty minutes, without a word being spoken by the operators.

The Towing Locomotives.

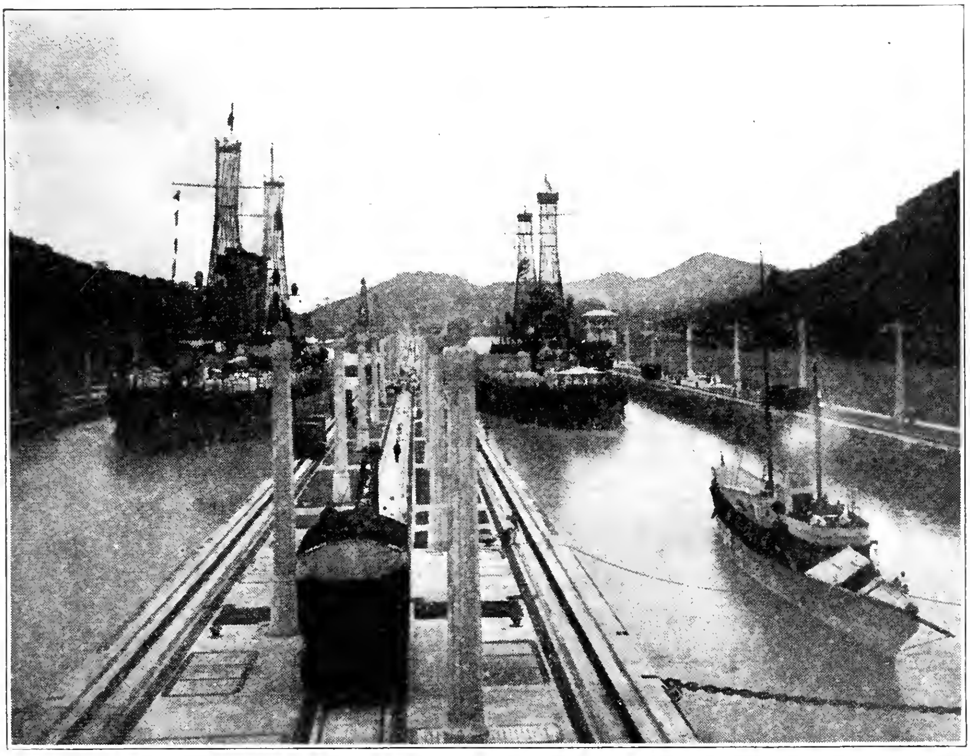
When the S. S. Cristobal was locked through on August 3, 1914, there was considerable delay at Gatun due to burning out of the grids on one of the forward locomotives. At Pedro Miguel a towing line was broken, owing to the coils on the drum having overlapped and binding, which prevented the drum from turning or slipping as the locomotive descended the incline. This delay was slight, as a spare locomotive was switched in and the lockage proceeded. Only four locomotives were used at each of these locks. At Miraflores six locomotives were used, and the vessel was handled without an accident of any nature, and at the full speed of two miles per hour. The vessel was stopped by the locomotives gradually in a distance of 125 feet after running at the two-mile speed. The following day the ship was successfully locked up. This demonstrated that the locomotives could handle the vessel successfully without the use of the ship's power.

A speed of two miles per hour was thought a little high for absolute safety, and it was found that this speed could be reduced to one mile per hour by concatenation of the traction motors of the locomotives. This was successfully tried out and a number of vessels were locked through at the one-mile speed. The pilots, however, were unanimous in the belief that the two-mile speed was the better, and that they could handle any vessel at that speed with absolute safety. All lockages are now made at the higher speed.

Plans are, however, on foot so that either speed may be available.

The lock pilots being accustomed to handling vessels with the engines, used the vessels' power a great deal at first and the locomotives principally for centering the ship in the chamber. After becoming familiar with the capabilities of the locomotives, they have been locking vessels with the use of locomotives almost entirely, and have finally favored the locomotive power exclusively, with the exception of helping the locomotives accelerate the ships from rest by a few turns of the screws. The mere fact that the pilots lock their ships through in this manner shows that the method is satisfactory. In fact, the pilots all state that it would be inadvisable to attempt to handle the vessels quickly without them.

The success with which vessels are now locked with towing



Operation of Pedro Miguel Locks. U. S. S. "Missouri" and "Ohio" in the Chambers. July 16, 1915

locomotives is indicated by an article in the *Canal Record* of August 25, 1915, reading as follows:

"'The commander of the United States Naval Academy practice squadron, consisting of the battleships Missouri, Ohio, and Wisconsin, which passed through the canal on July 15 and 16, on the way from Annapolis to San Diego, and comprised the first large war-ships to make use of the canal, has forwarded to the Navy Department a report on the passage through the canal. The report commends the promptness with which all needs of supplies were

met by the canal facilities, and states that promptness and exactness of arrangement marked every detail in the management of every department.

"'With respect to locking the Missouri and the Ohio through Pedro Miguel and Miraflores locks simultaneously in parallel with the Wisconsin directly in the rear, the report states that the centering and control of the vessels by the towing locomotives were so nearly perfect that a division of four ships of the size of these, or even somewhat larger, could be handled through at the same time, two in each of the duplicate chambers. In the case of dreadnoughts, the length of the ships would prevent the handling of more than one in each chamber, or two at a time. However, the entire present main battleship fleet, made up of four divisions of five ships each

Gatun Locks Control Board

and a flagship, a total of 21, could be passed through the canal in one day.

"'In all the operations, and especially during lockages, the commander of the squadron reported, there was no shouting or confusion at any time, but a celerity of working, in a silent, automatic sequence which showed that the mechanical arrangements were highly efficient and in charge of a well organized and capable force.

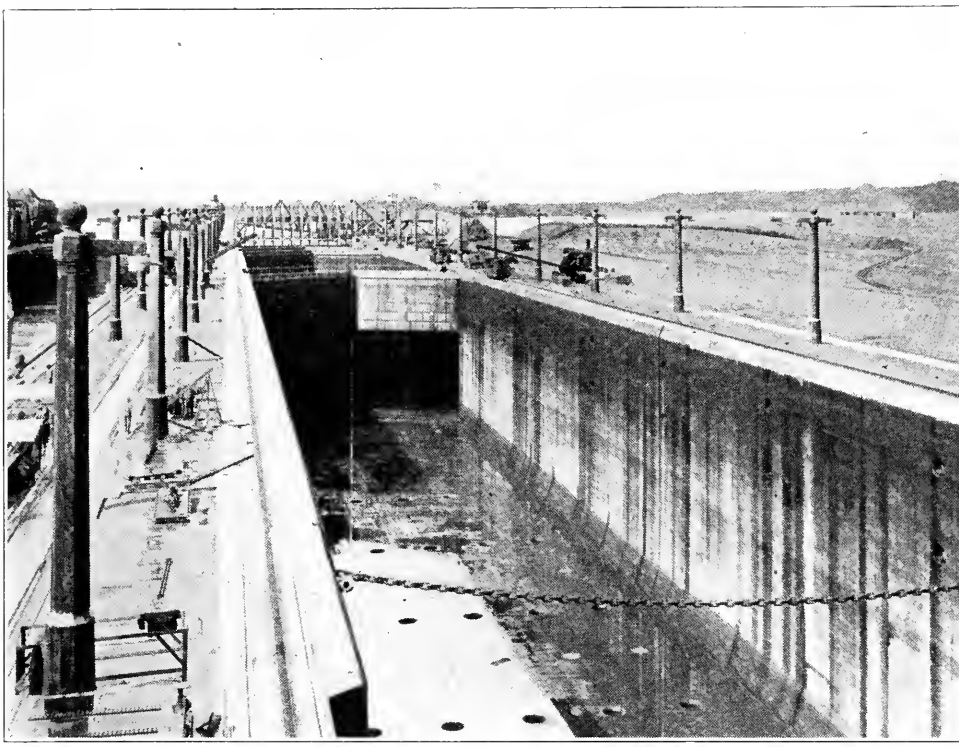
"'The squadron is due to reach Balboa about September 1 on its return voyage to Annapolis. In addition to the time required

for passing through the canal it will remain in canal waters 24 hours to allow the midshipmen to inspect the construction. Two thousand tons of coal will be taken at Cristobal.' "

Bids are now advertised for additional locomotives. The new locomotives will have a number of slight improvements, which is to be expected, as the locomotives were a novel feature and only hard service and experience could dictate improvements.

Remote Control Operation.

The unique feature of the Panama canal locks is the remote control system. A flight of locks is operated by a single operator,



Gatun Locks, Upper West Chamber Unwatered. July, 1915

who controls the lock machinery from a central point, and who can see by indicators the position of all the machinery and all water levels. For the main lock machines, the indicators operate in synchronism with the machines, or give progressive indications. The travel of the various machines is regulated by limit switches, which interrupt the current from the control house used to operate the machine contactors.

The remote control system eliminates a vast amount of complication and co-ordination required by local control, as the number of machines and the distances between machines is very great. For instance, at Gatun locks there are 204 machines operated from remote control, and the machinery or operating tunnels of the center wall are 4,100 feet long. The remote control system eliminates

loss of time in the sequence of operation and prevents accidents, as the correct sequence of operations is required by interlocks on the control board.

The locks at Gatun were first operated from remote control on May 13, 1914, and the system was put into effect at all locks on July 1, 1914. From that time on the remote control system has fulfilled all expectations. The only trouble experienced was that the contactors stuck and the machines overtraveled. The cause was ascertained to be due to the rebounding of the contactors after the limit switches caused their original opening. This was demonstrated by indicator diagrams, and an anti-rebounding device was furnished by the manufacturer, which has successfully overcome the trouble.

Handling of Water.

The locks are in duplicate sets with a common center wall. The water is distributed over the area of the lock through a large number of openings in the floor. These openings are connected in transverse rows to lateral culverts which alternately connect to the main longitudinal culverts in the side and center walls. The main culverts extend the length of the locks, connecting to the forebay at the upper end and tailbay at the lower end. The flow of water is controlled by rising stem valves which sectionalize the main culverts and cause proper diversion. The side wall laterals connect freely to the main culvert, and those to the center wall are equipped with cylindrical valves at the entrance point. The center wall culvert may be used for either lock, by opening the cylindrical valves to that lock and closing them to the opposite lock. Cross filling is frequently resorted to by opening the center wall laterals to both chambers. The system was designed with the expectation of obtaining a practically uniform water distribution under all conditions. With such a distribution it was expected to change the water levels at a maximum rate of three feet per minute. The side wall culvert was designed to give this rate for the major part of the operation by regulation of the valve openings, and the center wall culvert was intended as an auxiliary which might be used to accelerate the last few feet of flow and in this manner perform the entire change of levels in fifteen minutes.

The maximum rate when filling the 900-foot lock with the side wall culvert is 4.5 feet per minute, and with both culverts fully opened for the entire period the maximum rate is 7.5 feet per minute. The distribution for filling with both culverts is good, but for one culvert alone it is not all that was anticipated. In locking vessels up it is preferable to use both culverts with the 7.5-foot rate in preference to one with the 4.5-foot rate. It thus happens that on account of its effect on the total distribution, the center wall culvert, while originally intended as an auxiliary, has proven a very important factor in the safe and rapid handling of vessels.

No trouble whatsoever has been experienced in the handling of

vessels on "down" lockages, although it is known that the distribution is not uniform. Therefore, in the operation of the locks, vessels on "up" lockages are given preference for double culvert operation, and the center wall culvert is used on "down" lockages only for saving time. The remote control system makes it possible to change the center wall culvert from one lock to its twin in thirty seconds. With the present traffic, two culverts are generally available for all lockages.

With two culverts the lift of thirty-two feet is made in eight minutes, or a little more than one-half the time originally contemplated. The average flow amounts to 492,000 cubic feet per minute, and the maximum flow, 923,000 cubic feet per minute. A thorough investigation has been made of the hydraulics of the locks, and the uneven distribution has been accounted for, as well as many other interesting unusual phenomena.

The Rising Stem Valves.

In all cases except cross-filling between adjacent locks of the same level, the flow of water is controlled by pairs of rising stem valve machines.

This machine consists in a rising stem passing through a stuffing box in a water-tight bulkhead connected to a gate valve at the lower end and to a guided cross-head at the upper end. The cross-head is moved vertically through a distance of 18 feet by means of two vertical revolving screws which transmit the force through two non-revolving nuts in the cross-head. Each screw is driven from the motor shaft by a gear and pinion reduction and two bevel gears. Two sub-bases carry the motor, limit switch, extended shaft bearings and thrust bearings. The two live roller trains against which the gate travels when under pressure are constrained to move at half the rate of the gate travel by chains actuated by the cross-head. The chains pass over pulleys and are fastened to rods which pass through the stuffing boxes in the water-tight bulkheads. The lower ends of the rods are attached to the live roller trains. The two ends of the cross-head are slotted to allow the cross-head nuts to travel six inches after the valve has seated, and to allow the machinery to stop without shock.

Drawings of the rising stem valve machine, as well as the other main operating machines, appear in the journal of the Western Society of Engineers for September, 1914, being reproduced in a paper by Mr. L. D. Cornish.

Extensive tests have been made on the rising stem valves to determine their performance under various heads, and especially to determine the losses resulting from water pressure and the coefficient of roller train friction. Before the machines were put into operation their losses, when operating in the dry, were found to be as follows, all losses being reduced to equivalent forces at the valve stem:

Operation of the Valve in the Dry.

		Opening Valve. Lbs.	Closing Valve. Lbs.
(a)	Weight of valve and accessories, cross-head and equivalent weight of roller train	31,500	31,500
(b)	Side seal friction due to initial tension	1,000	1,000
(c)	Valve, stem and roller train friction	8,000	8,000
(d)	Equivalent weight on cross-head (a ± (b + c)	40,500	22,500
(e)	Coefficient thrust screw friction	.073	.083
(f)	Thrust screw sliding friction	23,900	14,700
(g)	Binding friction between nuts and screws	2,100	2,100
(h)	Losses in gearing between motors and screws	19,000	12,400
(i)	Total machine and valve friction (b + c + f + g + h)	54,000	38,200
(j)	Total force to move valve (i ± a)	85,500	6,700

480 revolutions of motor given an 18-foot movement of the valve. Motor synchronous speed is 500 r. p. m. It takes 63 seconds to open valve, and 58 seconds to close it.

The coefficient of roller train friction was found from dynamometer tests at Gatun Locks to be .025. Using this coefficient, the calculated losses for most severe condition of operation follow:

Opening Valve Under 79-Foot Head.

		Lbs.
(a)	Friction of side seals due to water pressure	4,170
(b)	Water pressure against top seal (upward force)	5,420
(c)	Rolling friction of roller trains (coefficient 0.0250)	16,250
(d)	Total added friction due to water pressure (a — b + c)	15,000
(e)	Total valve, roller train, and seal friction in the dry	9,000
(f)	Weight of valve and accessories, cross-head and equivalent weight of roller trains	31,500
(g)	Equivalent weight on cross-head (d + e + f)	55,500
(h)	Coefficient of thrust screw friction	.064
(i)	Thrust screw sliding friction	28,000
(j)	Thrust screw and nut binding friction	2,100
(k)	Losses in gearing between motor and screws	21,000
(l)	Total friction machine and valve friction (d + e + i + j + k)	75,100
(m)	Total force required to break seals (f + l)	106,600

The maximum equivalent weight (g) on the cross-head is calculated above as 55,500 pounds, including the weight of the cross-head and accessories—2,900 pounds. The machines were designed to exert a lifting force of 60,000 pounds at the cross-head, and before the final contract was awarded the first two machines successfully stood a test with 60,000-pounds load in addition to the weight of the cross-head.

The force for closing the valve is the same for all conditions of operation, as an increase of roller train friction is neutralized by the decrease of thrust screw friction.

Tests made under operation give the calculated force shown and demonstrate the correctness of the coefficient of roller train friction used. No increase of friction has been noted after two years' service.

The force while opening the valve is practically the same during the entire period, showing that the total pressure or head against the valve remains constant.

This is the result shown by observation, and the exact reasons are not at this time entirely clear.

The valves have been closed repeatedly against high heads when equalizing between chambers, with no noticeable surging or shock. The leakage under a 30-foot head is about 1.25 cubic feet per second per pair of valves.

The total discharge through the valves is not directly proportional to the opening; coefficients based on the area of the opening of the valves may greatly exceed unity due to the velocity of approach. In certain cases, such as equalizing between levels, it makes very little difference in the total flow whether one or both valves are open.

Operation of the Miter Gates.

Each set of miter gates was built to withstand full hydrostatic pressure, and at the time the locks were watered, this pressure was successively applied to each set. The main operating gates at Pedro Miguel are 79 feet high; their sill is at elevation + 13 feet. The maximum elevation of Gatun Lake is + 87 feet. If a lock chamber were unwatered, the upper operating gates would be required to withstand a 74-foot head of water. As each miter gate leaf is 65 feet in length, the full hydrostatic pressure per leaf would then be 5,550 tons.

In normal operation the maximum pressure on any set of gates occurs on the lower operating gates at Miraflores upper lock. The sill of these gates is at elevation — 18.3 feet. When the water in the lower lock is at low tide, or — 10 feet, and the upper lock at Miraflores lake level, elevation + 55 feet, the net pressure per leaf is 5,380 tons, practically equivalent to the maximum as calculated above.

The mechanism for the remote control of the lock gates is not equipped with an interlock to prevent the opening of a set of leaves before equalization of water levels. None is necessary, as the miter gate moving machines are just strong enough to operate the gate after equalization. For example, in the case of a difference of 2 feet in levels on the two sides of the upper operating gates at Pedro Miguel, there would be 74 feet of water against the upstream side, and 72 feet against the downstream side. This difference would result in a net downstream pressure of 600,000 pounds. With refer-

ence to the miter gate moving machine, this pressure may be considered as applied perpendicularly at the center of the leaf, or a distance of 32½ feet from the pintle. A perpendicular distance from the pintle to the center line of the strut of the moving machines is 11.5 feet, approximately, when the gate is closed. To open the leaf against a water pressure of 600,000 pounds, the strut would have to exert a force of about 1,700,000 pounds. The maximum force the strut can exert on opening a leaf is approximately 1,000,000 pounds, and an attempt to open a leaf under these conditions would stall the motor after compressing the springs in the strut.

On filling or emptying a chamber, the water overtravels, after equalization, and back pressure on the gates results. This back pressure varies from 6 to 12 inches, and causes the gates to open 8 inches between miter points, or to the full limit of strut spring compression. It requires 185,000 pounds to compress the springs solid, and a few inches is sufficient to do this. This helps to open the gates and also gives a positive signal that equalization has occurred.

In most cases there is a difference in density of the water on both sides of the operating gates, as with every lockage some salt water is locked up into the fresh water supply, as testified by the increasing salinity of Miraflores lake. When conditions of equilibrium are established after opening the culvert connecting the chambers on the two sides of the gates, the water levels are not always the same.

For instance, at the 82-foot gates at the lower end of Miraflores locks, which are generally kept closed while the culvert to the sea is kept open, the fresh water on the upstream side is from four to eight inches higher than the sea water on the downstream side. This difference depends on the difference of densities and also on the position of the culvert outlet.

Assume the outlet at elevation of bottom of lock, and suppose the relative densities to be as 1.02:1.00. The sill of the gate is —50 feet. High tide is +10 feet. With 60 feet of water on the downstream side of the gate, there would be 61.2 feet on the upstream side, or a difference in levels of 1.2 feet. The total pressure on the gate depends on the density and the square of the head. Consequently the net total pressure per leaf would be 150,000 pounds more on the upstream side than on the downstream side. To avoid this large difference in pressure, a specially constructed culvert outlet was placed at elevation —25 feet, or 25 feet above the sill. This makes the resultant levels for the above conditions 60 feet on the downstream side, and (60—25) 1.02 plus 25, or 60.7 feet on the upstream side, and reduces the net pressure to about 24,000 pounds per leaf.

In making lockages at Miraflores, the levels on the two sides of the lower operating gates in the upper chamber differ at times by 1 foot when equilibrium is reached between the upper and lower

chambers. The net pressure per leaf tending to resist the opening of a leaf for this condition is approximately 100,000 pounds. The gates are always opened when they "crack" from back pressure caused by the overtravel of the water before such a condition of equilibrium is reached; otherwise, it would put a severe duty on the miter gate moving machinery, and a heavy current would flow from the upper to the lower lock that would be undesirable, as soon as the gates were opened.

Another resistive force to the movement of a miter gate leaf is the difference in water levels on the two sides of a gate caused by the movement of the leaf; for instance, the area of the space between the upper guard gates and the upper operating gates is 11,000 square feet. If the upper guard gate is opened two feet, the area is enlarged by about 137 square feet. As the minimum immersion of the guard gate is about 40 feet, the volume displaced by this movement amounts to 5,480 cubic feet. This lowers the water on the downstream side about six inches, and creates a large resisting force to further outward, upstream movement of the guard gate until the difference in level is relieved by the influx of water through the opening between the leaves and through the auxiliary culvert. In a similar manner the upper operating gates are opened for using the 900-foot lock. For a 4-foot movement, assuming no influx, the water in the chamber would be lowered two inches, and the resistive force would be 50,700 pounds per leaf. It has been found from the duty cycle of the moving machine that the maximum torque occurs on opening the gate about twenty seconds after the gate is opened, and on closing, about twenty esconds before the gate is closed.

On account of the conditions just described, it has been found to be most satisfactory to open one of the leaves from fifteen to twenty seconds before the other. This gives about the same opening between leaves as a simultaneous opening, as they join at an angle of 120 degrees; and gives a comparatively light duty to the motors, as only half the water is displaced. In opening four leaves, such as the upper guard and upper operating gates, one of the guard leaves is opened first; five seconds later the operating leaf on the same side; fifteen seconds after this the other guard leaf; and five seconds after this, the second operating leaf. This method increases the normal time for opening the two gates by twenty-five seconds, but is much less severe on the operating machinery. For operating the gates in the dry, scarcely any power is required. The effect of eddy currents and backing-up of the water against the gate recess also tend to prevent movement of the gates, but these factors are small compared with those given.

When closing the gates the currents set up due to difference in salinity of water have a negligible effect on the operation of the gates. The currents caused by displacement of a vessel in motion or those resulting from use of the vessel's screw to date have had

very little effect (the canal being open only to vessels of 30 feet draft). Surges, however, are set up in the chamber having a total amplitude as great as one foot. These surges have a marked effect on the operation of the gates, resulting in positive or negative pressures, depending on the time the gate is closed with reference to the surge. The surges have, in general, a period of about one minute and a skilled operator can time the operation of the gates so as to avoid large positive pressures.

The displacement of the gate always tends to resist its motion, but the efflux rate for closing is greater than opening, due to the relative length of the strut in the two cases, the strut being elongated when opening and shortened when closing the gate by an amount equal to the compression of the strut springs. Where the areas controlled by the gate are large, it sometimes happens that the positive pressure caused by the surges mentioned is greater than the resistive pressure due to displacement, and the gates close with considerable violence. Consequently the operating gate leaves are operated simultaneously, so as to get the full cushion effect due to displacement.

Leakage.

The leakage through the gates is a negligible amount. Through the rising stem valves it amounts to about 1.25 cubic feet per second per pair of valves for a 30-foot head. The leakage through the cylindrical valves is as great as one cubic foot per second per valve, or ten cubic feet per second per chamber for 30-foot head. The area of the 900-foot lock is 123,000 square feet, so that the leakage causes changes in the levels at a maximum rate of one foot in about three hours, an amount that in no way interferes with operation.

Unwatering Lock Chambers and Inspection of Valves, Electrolytic Action, Etc.

During the month of December, 1914, the floating caisson arrived from the United States. This caisson is similar to, and for the same purpose, as caissons for dry docks; that is, to close off one end of the lock in order that it may be pumped dry for inspection and repairs. This caisson was placed at Miraflores locks and inspection of all culverts and under-water equipment made. The most important thing discovered was that the salt water was causing a galvanic action between the different kinds of metals, showing principally on the heads of rivets and on the steel strip on which the side seals of the rising stem valves bear. Investigation showed that with the salt water of the lock as an electrolyte, potential differences of an appreciable value existed between electrodes of steel and babbitt, steel and bronze and between bronze and babbitt, causing currents which almost invariably ate away the steel. While the voltage involved is of low value, the fact that it continues every second of the day results in a considerable wasting away of the metal. Tests have been made with the electrodes coated with various paints and compounds. Some of these insulated for a few

days and gradually deteriorated to such a point that within a month or so their value was practically nil. At least one, however, has held up and appears to have the property of holding up almost indefinitely, thus offering a solution to the problem.

Surges in Gaillard Cut and Overtravel of the Water in the Locks.

When water is drawn from a forebay for the purpose of filling a lock, the water nearest the intake is, of course, the first to begin movement, thus causing a considerable drop in the forebay level.

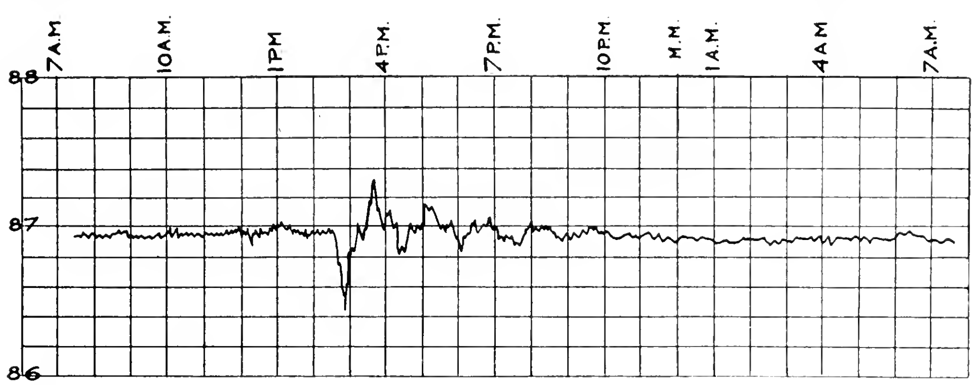


Chart No. 3

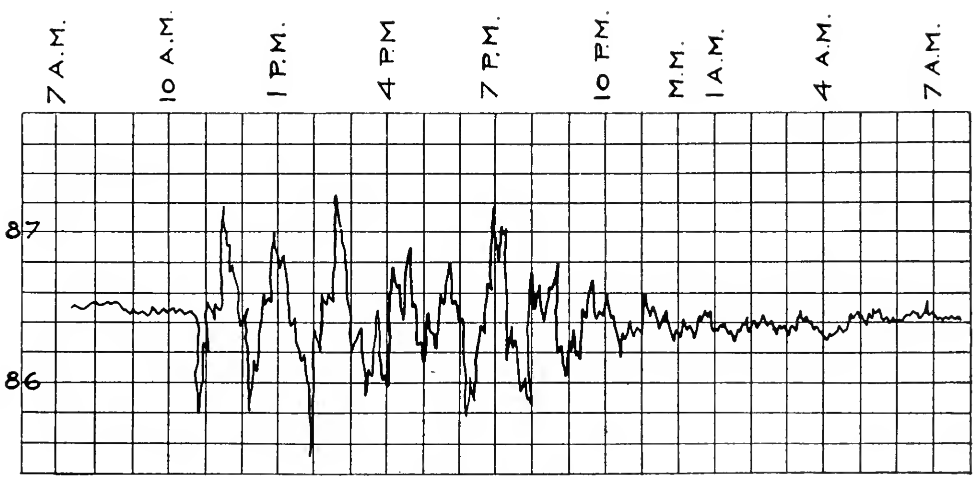


Chart No. 4

This drop gradually runs along a channel, forming a wave which oscillates for a considerable period of time. For example, the wave from Pedro Miguel locks is felt at the water-gauging stations on the Chagres river, and the result of filling a single lock chamber is in evidence for a period of over two hours. If water for successive lockages be drawn so as to continually depress the elevation of the forebay, the wave will be built up and magnified. This is illustrated by the charts, one chart showing the effect when but one lock chamber was drawn, and the other showing the wave that was built up on an unusually busy day. Owing to the eddy currents

along the channel and the movement of self-propelled dredges and tugs, these waves appear in some respects to be a little erratic. More attention is being paid to this point, in order that water may be drawn at the proper interval, preventing the creation of a wave of dangerous amplitude. With the amplitude of nearly 2½ feet shown on chart No. 4, no difficulty was experienced by the ships traversing the channel.

With the slides in their present condition, a narrow channel is formed at one part of the cut, where high velocities of the water exist. Owing to these high velocities, water is drawn at Pedro Miguel Locks with extreme caution, for two reasons: The rapid current would interfere with the necessarily careful maneuvering of the vessel, and, with a limited depth of channel at this point, the water level might be drawn down sufficiently to ground the ship temporarily.

As previously mentioned, the miter gates crack open from back pressure due to the overtravel of the water in the chamber compared to the level the water is drawn from. This overtravel is due to the dynamic action of the water in the lock culverts, on account of its decreasing velocity while filling or emptying a chamber. In consequence of this action, the filling and emptying curves do not follow the ordinary simple formula, and the water overtravels by an amount proportional to the length and area of the culvert filling or emptying the lock, and inversely proportional to the area of the lock chamber. This overtravel is a very helpful phenomena, as it results in a decreased duty cycle on the miter gates when opening them, and saves considerable time in filling or emptying the locks, due to the fact that the slowest changes in level occur after actual equalization.

Currents in the Locks.

When the side-wall culvert is used for filling, the water rises from the bottom of the lock next to the center wall at a greater rate than along the side wall. This tends to carry a vessel towards the side wall. If there is a quantity of salt water in the chamber when filling begins, the tendency to force the vessel toward the wall, the culvert of which is being used for the filling, is especially great. This reason is that, in addition to the normally more rapid rise along the opposite wall, the fresh water is forced to the top with augmented velocity by the pressure of the denser salt water.

This tendency was distinctly demonstrated during the up-lockage of the Santa Clara through the Pacific Locks on June 18th. In the lower chamber at Miraflores, when the side wall culvert was being used, the towing locomotives could not hold the vessel away from the side wall. In the upper chamber where the water was comparatively fresh, this trouble was not experienced. At Pedro Miguel, both culverts were used and the vessel remained in the center of the chamber with hardly any effort on the part of the locomotives. All merchant vessels are required to have their sides

clear before passage through the Canal, so that they can rub against the lock walls without injury.

In filling a chamber, the surface disturbance of the water is considerable. Several small row boats have been swamped by it. In emptying, the surface is placid and there is scarcely any tendency to move a vessel. No tendency toward movement of vessels along the axis of the locks has been noted in either filling or emptying.

It has been observed that in all cases where a gate is opened after equalization between water of differing salinity on its two sides, there is a heavy surface current from the fresh to the relatively salty water.

An investigation was made at Miraflores Locks to determine the maximum average current velocity at various depths; in other words, to determine the current velocity for ships of various drafts. Seven telephone poles, of lengths from four to thirty-five feet, were assembled in Miraflores Lake and weighted, so that they would float in a vertical position, with only a foot or so protruding above the surface. These floats were locked through the west flight of Miraflores Locks, from Miraflores Lake to the sea, and the effects of the currents noted by plotting the positions of the floats against time.

In all cases, the gates were opened immediately after they cracked from back pressure, and the floats were released at the center of the chamber, on the north side of the opening gates, in a position as near the gates as a vessel would be allowed. The lockage was made when the Pacific was at low tide; the depth of water over the sill of the upper lock and over the sill of the lower lock was 41 feet, on equalization for the respective openings of gates.

Observations were made of the currents set up on opening the upper gates, between Miraflores Lake and the upper level; on opening the operating gates between the upper and lower levels; and on opening the lower gates, between the lower level and the Pacific channel.

On the opening of the upper gates, there was plainly discernible a surface current toward the lower end of the chamber. This current ran to the end of the chamber, when a reverse current was set up; the shorter floats traveled at the rate of this current and reversed with it at the lower end of the chamber. The shorter floats remained in a vertical position, but the longer floats leaned as much as 30 degrees from the vertical, and rose and fell a distance of about three feet. This indicated that the longer floats were affected by a current below in a reverse direction from that of the top current. The shorter floats remained in the center of the chamber until they reached its end, but the floats immersed to a depth greater than 20 feet drifted toward one side or the other during the observations. The maximum velocity was attained by the surface floats, and amounted to 1.2 miles per hour. The 30-foot float had a maximum velocity of only 0.2 mile per hour.

On opening the operating gate between the upper and the lower level of the locks, with the water in the two chambers equalized, the effect on the floats of respective lengths was practically the same as when the gate was opened between the lake and the upper level, except that the floats traveled at a faster rate. The maximum velocity was 2.3 miles for the surface float, and 0.4 for the 30-foot float. This is ascribed to a greater difference in density of water on the two sides of the gate than was the case in locking the floats from the lake to the upper level.

The strongest currents were obtained on opening the lower gates, between the lower level and the sea. Since there was no obstruction to the outward flow of the relatively fresh water, there was no reverse surge on the surface. There was, however, a steady decrease of speed as the forebay widened. The maximum velocity was 2.80 miles per hour for the surface float and 0.8 mile for the 30-foot float.

In the test at the lower end of the locks, the shorter floats floated down the center of the locks, turning to the west on leaving the forebay. The tendency to float to the west on leaving Miraflores Locks had been observed before in barges and other vessels of light draft, and the path taken by such vessels when allowed to drift free was the same as that of these floats. The two shorter floats remained in a vertical position throughout the operation, but the others had at times an inclination as great as 30 degrees.

No trouble has been experienced due to these fresh-salt water currents while the locomotives have control. The current from the lower locks to sea makes it somewhat difficult for a vessel to leave the locks in it, as there is a very strong tendency to carry the ship over toward the bank of the canal as soon as the ship is outside the locks.

The vessel can be held until the current subsides in the lock chamber, but this means a delay of 30 minutes. Accordingly, the plan adopted is to bring the vessel up to speed with the locomotives and cast off the lines in the chamber before the ship leaves the locks. The vessel can then pick up sufficient steerage way before leaving the locks to care for itself.

The theoretical values of these currents have been ascertained and confirmed by meter tests. It has been found that the volumes of water set in motion by these currents between the lower lock and the sea are of the same magnitude as the full culvert discharge into the tailbay. The installation of dolphins in the tailbay to prevent vessels from assuming a cross-wise position due to these currents is now under consideration. The currents constitute the most objectionable feature in the operation of the locks, but there seems to be no way of avoiding them. The location of the culvert outlet as previously mentioned, in addition to reducing the net pressure on the miter gates, decreases the initial values of the currents.

Discussion.

W. W. Deberard, M. W. S. E. (Chairman): The thing that occurs to me in all these locks is the fact that we go on building time and again the same size openings from one side to the other. Why do not designers vary that opening?

Mr. Grauten: I do not know that I can explain exactly why it is always done, but it must be taken into account that the same culverts which are used for filling are also used for emptying the lock. You could design a very efficient nozzle for a hoze to spout water out but that same nozzle has to be used with a reverse direction. That is not true in all cases, but in most of the culverts of the lock it is true.

Mr. Deberard: That is a very good reason, but, on the other hand, the downward motion, of course, never causes very much trouble. It is only the influx of the water that gives any difficulty.

Mr. Grauten: I think Mr. Beyer may have some interesting things to tell about the lighting and the aids to navigation. Perhaps the only difficulty would be that there would be time for him to tell us but a small part of what he knows about it.

W. F. Beyer: The range towers were located quite differently from what had heretofore obtained in the states, and, in fact, even in European countries. In these countries the towers are located on the axis of the canal or dredged channel. Any of the narrow channels such as they have down in Panama, 500 feet wide, some 800 feet wide, are very much like those in rivers or channels connecting great lakes, where the channels are about 300 feet wide. They are widening them nowadays to 600 feet and still difficulty is experienced in operating ships, especially in passing one another, in that a large ship would hold the range almost absolutely, the captain of a larger ship forcing a smaller ship to take the side of the channel, thus jeopardizing the smaller ship. In Panama we changed that by locating one set of ranges, that is, the head range, from 100 to 125 feet to starboard of the axis of the canal for ships going north, and 125 feet or 100 feet to the starboard of the axis for ships going south, which would make from 200 to 250 feet center to center of ships passing each other. This gave them good clearance with no danger of one ship being brought up to the other by suction, which is a very common cause of accidents in narrow channels. The horizontal distance between the range towers, of course, was governed by the length or reach of the sailing course. That is usually about ten per cent of the length of the sailing course. The vertical height depends upon the topography of the country. We tried to use as small a vertical angle as possible, but the topography of the country in some cases made it necessary to use quite a large vertical angle. In Culebra Cut no ranges were used at all because the precipitous hills would not permit obtaining sufficient horizontal distance between the ranges. The towers are built entirely of reinforced concrete. They are of simple design and a departure

from anything that has heretofore been built. That is due, of course, to the climatic conditions. In the tropics we can go to the extreme limit with reinforced concrete construction. The walls of the towers are only five inches thick at the top and seven at the bottom. The height of the towers ranges from thirty feet to ninety-five feet. They are eight feet in diameter at the top and about thirteen feet in diameter at the bottom for the tallest towers. Wherever it is possible we used electricity for the illuminant, but in the Gatun Lake region the cost of an electric installation would have been prohibitive, so acetylene gas was used; that is, compressed acetylene dissolved in acetone.

Instead of having fixed lights or so-called steady lights, all lights are flashing, each light having its own characteristic. For instance, the front tower of a range would have a characteristic of three-tenths of a second light and seven-tenths dark, whereas the rear light, so that it could be distinguished from the front light, would have the characteristic of three-tenths light and three-tenths dark, the latter giving practically a twinkling light. The side lights or other lights in the vicinity of range towers which might be mistaken for the latter have a characteristic, something like three-tenths second light, two and seven-tenths dark, three-tenths light, two and seven-tenths dark; and the lights on the opposite bank of the channel have a characteristic something like five seconds light, five seconds dark; while those at turning points have characteristics of three-tenths second light, seven-tenths second dark, three-tenths light, one and seven-tenths dark. By actual experience we found that the characteristics were perfectly feasible, although they were pretty hard on the pilots at first. They balked at anything that was quite different from their old style of fixed lights. But since the pilots have been more accustomed to the new system, they claim it is superior to the old.

Mr. Deberard: At the time of the Eastland disaster, or shortly thereafter, there was a great deal of discussion by one or two of the newspapers in Chicago in regard to the possibilities of what might happen if the Wells Street bridge was open and one of the Northwestern Elevated trains came down and dropped into the river. One of the more stable newspapers took the precaution to send a man to the elevated people to ask the superintendent to tell him just how they operated the bridge so that trains could not get into the river. If I remember correctly, there were no less than half a dozen different switches that had to be thrown in order, before the train could start over the bridge after the bridge had been thrown back into position. The pictures shown here of those marvelous tables some twenty feet long show how you can put in small compass a whole series of operations. You could not do that in any other way than by electricity.

Does the bull-wheel operating the gate come around to a dead stop, or does it oscillate back and forth?

Mr. Grauten: At Panama the bull-wheel is operated so that the motor is cut off some five or six inches before the pin actually reaches the dead center and the inertia of the moving parts carries it practically up to the dead center, but there is no over travel. There might be a fraction of an inch in some cases, but there is none purposely.

Samuel T. Smetters, M. W. S. E.: Was there any tendency to trap the air in the intake water in any of these conduits?

About the surging of the water, I have always found that on the surface the velocity is much higher than below the surface and that is true even in slips along the river. You will find there is always a current in at the surface and a current out below. That is one reason debris will flow into slips on the river along the surface, but the chance of anything that is water-logged getting into a slip is not very great.

Mr. Grauten: About the entrapping of air, in the early operations, for instance, the upper lock at Gatun was empty, and in filling it we made some experiments at various rates, some quite rapid. With the rapid rate of filling through a vortex formed in front of the intake some air will be entrapped, but in ordinary operation there is no trouble from that source.

As to the flow of water in a similar case to the one spoken of, of a slip having the debris deposited in the outgoing current underneath, the currents in the locks that were investigated most thoroughly were those due to the difference in the salinity of the water and to a certain extent due to rapid filling and emptying; but I could not state except what was found in those experiments quoted at Miraflores where the float was used, a long telephone pole. There the current on the surface was in one direction and the inclination of the telephone pole showed there was a counter current underneath which would drag the pole in the opposite direction; not enough to move it in that direction, but enough to twist it in the opposite direction. That, of course, was due to the difference in salinity; that is, the mixing of the fresh and salt water.

E. N. Layfield, M. W. S. E.: One other point that may not be in Mr. Grauten's line, is the question of the grade, up which the electric locomotives run. In the cut it looks as if it were almost forty-five degrees. Of course, that is due to the foreshortening effect in the picture. Do you know what the grade is?

Mr. Grauten: The grade is one on two, which is a little less than fifty per cent. It figures about forty-eight per cent.

Frank H. Bernhard, ASSO. M. W. S. E.: I would like to ask in regard to the electrolytic corrosion effect. Has there been enough corrosion to affect the stability in the structure, or, if not a great amount of corrosion has been as yet noticed, is it expected that the stability of any of the structures will be affected by continued corrosion, unless it is checked?

Mr. Grauten: In the first nine months of operation, which is

the limit of my experience, there was no corrosion worth mentioning; and in the period covered by the paper, which covers practically the following year, the effects were apparently not serious. It is, I believe, the intention to make inspections at least once a year. All of the structural parts of the gates are protected by a coating, and one coating, as was stated in the paper, has been found which is a very good preventative of this action. Of course, this coating can not be used on the pintles and the moving parts, but those parts are easily replaced at the annual inspections should it become necessary.

A Member: What is that coating?

Mr. Grauten: The coating used is a paint called bitumastic enamel. It is a heavy paint, which looks more like tar than anything else.

J. W. Lowell, Jr., ASSO. W. S. E.: I would like to ask the speaker if he made any inspection of concrete about the locks and can tell us whether or not the salt water has had any effect upon the concrete, and if so, whether that would be any serious effect.

Mr. Grauten: That I could only state from what is said in the paper, and apparently if any serious effect had been found it would have been noted. But in the first year's operation we had no way of unwatering what was once salt. That is, the caissons had not been delivered and when the sea was once in there was no way of getting it out until these caissons arrived. But from what was said in the paper I believe that no serious effects were found in concrete; in fact, I do not know of any.

Mr. Beyer: There could not have been any trouble from the effect of salt water because that part is all mass concrete. There is no reinforced concrete exposed to sea water, as far as the locks are concerned. At the south end of the Gatun locks the center wall is a cellular wall of reinforced concrete, and, of course, the salt water does not get up to that part of the locks.

I have written to the Governor of the canal for some data on the effect of salt water on reinforced concrete piers and wharves down there and I also asked for some data concerning test slabs that I had made while I was on the Isthmus. Those test slabs are about four inches thick and reinforced in the usual way. Two of the slabs were mixed with fresh water and two mixed with salt water. After the slabs had hardened for about two months we put them out in Panama Bay, where they would be alternately exposed to salt water and fresh air at intervals of every six hours, due to the rise and fall of the tide, and I have written down there to have those slabs brought in if they are still there and have them broken. We have a record of and marks on the slabs so that we can tell whether the slabs mixed with fresh water or salt water have been affected.

Mr. Lowell: Did you notice any peculiarities in mixing the concrete with sea water, using the mixture? You said you made one slab mixed with sea water.

Mr. Beyer: In the regular construction down there we did

not use any sea water in the construction of reinforced concrete; where it was necessary to have the reinforced concrete exposed to the sea water it was either cofferdammed or built ashore in the form of concrete caissons and launched, taken out to their sites, and sunk. But we were very careful not to use any salt water in mixing the concrete.

Mr. Lowell: That was reinforced concrete?

Mr. Beyer: That was reinforced concrete. We paid no attention whatever to mass concrete.

Mr. Lowell: You used salt water for mixing that?

Mr. Beyer: Yes. Salt water has no deleterious effect on mass concrete.

Mr. Lowell: Did not affect the setting or anything of that kind?

Mr. Beyer: It set a little bit more slowly. That was the only noticeable thing about it.

Mr. Layfield: Was that the full strength sea water?

Mr. Beyer: Yes.

Mr. Smetters: I would like to ask what stone was used for concrete there.

Mr. Beyer: They used an Andesite rock at the Atlantic side, which was obtained from the quarries of Porto Bello, about twenty-five or thirty miles down the coast; and on the Pacific side they used a rhyolite rock, which was blasted from the hill at Ancon. This at times was not very clean.

Mr. Smetters: And the sand?

Mr. Beyer: On the Pacific side the sand was obtained from Chame Point, about twenty miles down the coast. That was good, clean sand. That on the Atlantic side was obtained from a point about forty miles down the coast and was not as good a sand as that on the Pacific side. There were pebbles in there a quarter of an inch in diameter; a very, very coarse and unsatisfactory sand for reinforced concrete. It was all right for mass concrete.

Mr. Smetters: The sand that was used in reinforced concrete work you got from the salt water, did you not?

Mr. Beyer: Yes.

Mr. Smetters: That was not washed for the fresh water?

Mr. Beyer: No, it was not washed at all.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

REINFORCED CONCRETE CONSTRUCTION. By George A. Hool. Vol. III. McGraw-Hill Book Co., Inc., New York. 688 pages. Price, $5.00.

The author requires no introduction to the students of the principles underlying Reinforced Concrete design. Volumes I and II, covering the field of fundamental principles, Retaining Walls and Buildings, are accepted as standard works. Volume III is devoted entirely to Bridges and Culverts, the treatment of the subject being comprehensive and thorough.

The contents is divided into eight general divisions—Part I, covering Arch Bridges; Part II, Slab and Girder Bridges; Part III, Culverts; Part IV, Notes on Construction Plant; Part V, Notes on Estimating; Part VI, The Artistic Design of Concrete Bridges; Part VII, The Construction in Detail of Several Types of Concrete Bridges; Part VIII, European Concrete Bridges.

An interesting feature of the book is the inclusion of chapters by other authors, who have given special attention to some of the subjects treated. While this may be considered as detracting from the uniformity of the structure of the book as a whole, it has the advantage of placing the subject matter before the reader in a highly specialized form.

Part I is noteworthy in containing "Arch Analyses by the Methods of the Ellipse of Elasticity," a method which was practically unknown to American engineers a few years ago. Although the advantages of this method may not be apparent to the average practicing engineer, the student of arch analysis will appreciate having this method clearly and fully developed in a standard treatise on Arch design. Part I also contains a full development of the standard methods of Arch analysis with detailed application to specific examples and a wealth of designing data and diagrams to assist the designer.

Perhaps one of the most valuable features of the book to the structural engineer is the abundance of details of construction and illustrations of completed structures, as well as bridges in process of construction. Fortunately for posterity, more and more attention is given to the appearance of bridges. The competency of a brige designer is no longer judged entirely by his ability to design a cheap, but also by his skill in making a beautiful structure. This phase of the subject is emphasized by the author in devoting two chapters to The Artistic Design of Concrete Bridges.

In general the book is a very valuable and welcome addition to the literature on the subject. A. E. L.

THE ENGINEER IN WAR. By P. S. Bond, Corps of Engineers, U. S. Army. McGraw-Hill Book Co., Inc., New York, 1916. 187 pages. Illustrated. Leather bound. 7½ in. by 5 in. Price, $1.50.

Major Bond in this book presents in a concise but very complete form the relation of engineering to the conduct of a modern war. He also presents the adaptation of the principles of civil engineering to military requirements in a very clear and logical manner.

This book cannot be too strongly recommended to the civilian engineer, to the National Guard officer, and to all those who desire to get a knowledge of the underlying principles of military engineering.

To summarize, the book contains practically all of the information which has been so eagerly sought by our patriotic civilian engineers. It should not only be read, but should also be studied, by *all* of our civilian engineers.

The book contains, besides a Bibliography and Glossary of Terms, eleven chapters on the following subjects:

The Military Policy of the United States; General Duties of the Military Engineer and Economics of Military Engineering; Tools and Equipment Employed in Military Engineering; Stream Crossings; Military Roads; Field Fortification and Siege Operations; Military Demolitions; Military Reconnaissance, Sketching and Surveying; Military Sanitation; The Mobilization of Material Resources; How May the Engineers and Contractors of America Prepare to Meet the Military Obligations of Citizenship? H. B. S.

THE AMERICAN CIVIL ENGINEERS' POCKET BOOK. By Mansfield Merriman, Editor-in-Chief, Third Edition, Revised and Enlarged, 1571 pages, 4 by 7 inches. John Wiley & Sons, New York. Price, $5.00 net.

Since the publication of the first edition of this pocket book in 1911 it has become a recognized standard and is so well known to most engineers that little need be said about it, except to comment on the additions and changes in the third edition, just issued. It will be remembered that each chapter was written by an expert selected by Professor Merriman, the Editor-in-Chief, these experts including some of the leading engineers of the country—among them the late Alfred Noble.

In the original preface, the Editor-in-Chief stated that "regarding typography, it has been the aim to render this pocket book more legible and artistic than any heretofore published. All type is leaded and there are no tables reading lengthwise of the page. The effort has been made to economize space at every step, when this did not conflict with the rules of good typography."

In the second edition, two new sections of "Steam and Electric Engineering" and on "Highway Engineering" were added, and in order to make the book cover the field of Civil Engineering more completely, still another section has been added in the present edition, on "Harbor and River Works."

The contents of the present edition are as follows:

Section 1—Mathematical Tables, Mansfield Merriman.
Section 2—Surveying, Geodesy, Railroad Location; Charles B. Breed.
Section 3—Steam and Electric Railroads, Walter Loring Webb.
Section 4—Materials of Construction, Rudolph P. Miller.
Section 5—Plain and Reinforced Concrete, Frederick E. Turneaure.
Section 6—Masonry, Foundations, Earthwork; Ira O. Baker.
Section 7—Masonry and Timber Structures, Walter J. Douglas.
Section 8—Steel Structures, Frank P. McKibbon.
Section 9—Hydraulics, Pumping, Water Power; Gardner S. Williams.
Section 10—Water Supply, Sewerage, Irrigation; Allen Hazen.
Section 11—Dams, Aqueducts, Canals, Shafts, Tunnels, Alfred Noble and Silas H. Wooward.
Section 12—Mathematics and Mechanics, Edward R. Maurer.
Section 13—Physics, Meteorology, Weights and Measures; Louis A. Fischer.
Section 14—Steam and Electric Engineering, George A. Goodenough and F. Malcolm Farmer.
Section 15—Highway Engineering, Arthur H. Blanchard.
Section 16—Harbor and River Works, Frederic R. Harris.

An index of seventy-five pages, carefully prepared, is a valuable part of the book.

CONCRETE CONSTRUCTION FOR RURAL COMMUNITIES. By Roy A. Seaton. McGraw-Hill Book Co., New York. 220 pages, 5 inches by 8 inches. Price, $2.00.

The author, who is professor of applied mechanics in the Kansas State Agricultural College, has put forth a book that is intended to serve as a textbook in agricultural colleges, and at the same time be useful to the non-technical man who has to construct concrete work occasionally for farm and

road work and similar purposes. The book is well written and well adapted for the purpose.

The contents are as follows:

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Meeting No. 934, April 3, 1916.

The regular meeting of the Society was called to order at 7:45 p. m. by Mr. W. W. DeBerard, Chairman of the Hydraulic Sanitary and Municipal Section.

The Secretary reported from the Board of Direction that at their meeting held this afternoon the following were elected to membership under the grades indicated:

George E. Ackerman, Chicago	Member
Henry W. Nichols, Chicago	Member
Robert P. Waters, St. Joseph, Mo.	Associate Member
Stanley W. McCassy, Chicago	Associate Member
O. A. Bailey, Chicago	Associate Member
Rowland Manley, Chicago	Junior Member
Harry M. Conklin, Clear Lake, Ia.	Junior Member
George D. Griswold, Chicago	Junior Member

And that applications for membership had been received from the following:

John Stone, Chicago.
Walter Painter, Chicago.
Orville H. Taylor, Beaver Dam, Ky.
Frank L. Orr, Des Moines, Ia.
Paul R. Huensch, Chicago.
Anthony L. Harth, Chicago.
B. B. Sostheim, Chicago.

The secretary also reported the death of Mr. Lightner Henderson, M. W. S. E., on March 17th, and that Mr. L. P. Moorhouse, Honorary Member and the first Secretary of the Society, died on March 18th.

Mr. Wharton Clay, M. W. S. E., a member of the Committee on Civilian Military Reserve, described a course of lectures to be given by officers of the Corps of the Engineers, U. S. Army, and others under the auspices of the Joint Committee on Military Engineering.

The paper of the evening on "The First Years' Operation of the Panama Canal Locks," by Mr. F. C. Clark, Superintendent and Mr. R. H. Whitehead, Assistant Superintendent, was read by Mr. H. S. Grauten, who had charge of the testing and putting in service of the entire electrical, mechanical and hydraulic equipment at Gatun and operated the Gatun Locks for the first nine months. Discussion followed by Messrs. W. F. Beyer, S. T. Smetters, E. N. Layfield, F. H. Bernhard, J. W. Lowell, Jr., and W. W. DeBerard.

The meeting adjourned at 10:30 p. m.

Meeting No. 935, April 17th, 1916.

The meeting was called to order at 7:45 p. m. with Mr. W. W. DeBerard, Chairman of the Hydraulic Sanitary and Municipal Section, in chair and about one-hundred members and guests present. The paper of the evening, "The Construction of the Wilson Avenue Tunnel," was read by the author, Mr. Henry W. Clausen, Assoc. W. S. E. The work described in the paper was being done under the direction of Mr. Clausen and was being carried out with a high degree of economy and satisfaction by day labor employed by the City of Chicago. The paper was well illustrated by lantern slides and many interesting features of the work were brought out. Discussion followed by Messrs. John Ericson, D. W. Mead, J. W. Mabbs, George B.

Springer, H. B. Kirkland, Murray Blanchard, John T. Walbridge, S. G. Artingstall, Sr., and E. N. Layfield.

The meeting adjourned at 10:45 p. m.

Meeting No. 936, April 24th, 1916.

A joint meeting with the Chicago Section of the American Institute of Electrical Engineers was called to order at 7:40 p. m. with Mr. C. A. Keller, Chairman, Electrical Section W. S. E., in the chair and about ninety members and guests present. The program for the evening consisted of four short papers on the general subject of "Central Stations in Cities of Less than 50,000 Inhabitants," these papers being as follows: "Thoughts in Connection with the Electrical System of Small Central Stations," by Mr. Albert J. Goedjen; "Station Management," by Mr. Adam Gshwindt; "Distribution of Electrical Energy with Particular Reference to Small Communities," by Mr. A. Hardgrave; "The City Manager," by Mr. R. L. Fitzgerald. Discussion followed by Messrs. J. N. Hatch, A. C. King, and P. Junkerfeld.

At the request of President Grant, Mr. Junkersfeld, who is one of the Illinois Directors of the Naval Consulting Board of the United States, described the work of that Board in connection with the investigation that is being made of the industries of the United States with a view of their utilization to the best advantage in the case of national emergency.

The Directors for the State of Illinois, Messrs. F. K. Copeland, William Hoskins, W. F. M. Goss, Robert W. Hunt, and P. Junkersfeld, are members of the W. S. E. The work is being conducted from the office of the Society.

The meeting adjourned at 10:30 p. m.

Excursions

Field Museum.

On Saturday afternoon, April 1st, about one-hundred members of the Society and their friends made an inspection trip to the New Field Museum Building on the Lake Front near 12th street on the invitation of Mr. Carman, representative of the architects. This building is 706 ft. long and 350 ft. wide, and is of a monumental character. The work was at an interesting stage and there were numerous interesting features in connection with the work, which was at a stage that permitted them to be seen advantageously from an engineering standpoint.

Union Stock Yards.

On Saturday afternoon, April 15th, about seventy-five members and their friends made a trip to the Union Stock Yards for the purpose of inspecting the Union Stock Yard Softening Plant, the Sanitary District Sewage Testing Station, and Armour & Company's Experimental Activated Sludge Plant.

After inspecting these plants a meeting was held in the Assembly Hall of Armour & Company and the chief chemist of that company, Mr. Paul Rudneck, read a short paper on the drying of Activated Sludge and its commercial value.

Journal of the Western Society of Engineers

Vol. XXI. MAY, 1916 No. 5

THE WILSON AVENUE WATER TUNNEL, CHICAGO

By H. W. Clausen, Assoc. W. S. E.,
Presented April 17, 1916.

PRELIMINARY

The Wilson Avenue Water Tunnel was planned to provide additional supply to the northwest portion of Chicago and also to give an additional supply to the Lake View Pumping Station.

By means of short stub connecting tunnels with sluice gates at the Lincoln Avenue and North Lawndale Avenue shafts future branch extensions can be constructed from the main tunnel as well as a direct extension westward from the gate shaft near North Lamon Avenue. A short 8-foot connecting tunnel south from the shore or Clarendon Avenue shaft is already completed and connected to the Lake View Pumping Station. An 8-foot tunnel connection will also be made between the old Lake View crib and the Wilson Avenue tunnel, thus permitting of the continual use of the old Lake View tunnel and the ultimate abandoning of the old Lake View crib.

The main 12-foot and 13-foot tunnel, which will be of 350 million gallons per day capacity, was located in Wilson Avenue in order to give the shortest direct route between the selected site for the Mayfair Pumping Station and the new crib to be located three miles from shore directly east from the end of Wilson Avenue. The government maps showing soundings and currents in Lake Michigan indicated that the location for the crib three miles from shore was as good as any, unless a very much greater distance was to be considered.

In order to have positive information regarding the soil to be traversed diamond drill borings were made along the route of the tunnel. These borings were located about a quarter of a mile apart for the land portion and included six holes in the lake portion.

These borings were made with the city's own forces by two drilling outfits, one steam driven and the other gasoline driven. Both machines did excellent work. The average cost per foot of bore hole was about $1.75.

The borings indicated that the best, quickest and cheapest results would be obtained by driving the tunnel through the solid limestone rock instead of the more or less treacherous soil above, and the plans for the tunnel were accordingly so drawn.

The necessity for supplying water to the Mayfair Pumping Station at the earliest possible date made it imperative that the best method of handling the work be devised. Past experience seemed to show that the contract method was more or less unsatisfactory, both on account of the specified time limit generally being exceeded and on account of the great likelihood of disputes arising and the meeting of unexpected conditions resulting in lawsuits afterward.

The only tunnel of this size previously constructed in Chicago was the Southwest Land and Lake Tunnel, which is about 10½ miles in length. Three miles of this tunnel is 14 ft. in diameter, three miles is 12 ft. in diameter, and four and one-half miles is 9 ft. in diameter.

On previous contracts for similar work the time set for completion was usually exceeded, the work being exceeded in some cases more than two years after the date set for completion.

The lake section of the Southwest Land and Lake Tunnel, about 2¾ miles of 14-ft. tunnel, including the intake crib, took from March, 1907, to January, 1912, or nearly five years to complete, notwithstanding the fact that an intermediate crib was used. An intermediate crib being only of a temporary character is always a source of danger from fire as well as being a great additional expense. It was believed that the lake section of the Wilson Avenue Tunnel could be constructed in a reasonable time without an intermediate crib if proper methods were employed, and consequently it was decided to construct the tunnel without such an intermediate crib.

The work was divided into three divisions: Section 1, including the crib, intake shaft and about 2,000 feet of 13-ft. tunnel extending westerly therefrom; Section 2, including the shore shaft and about 3,800 feet of 13-ft. and 17,500 feet of 12-ft. tunnel and also an 8-ft. connection to the Lake View Crib, and Section 3, including the Lincoln Avenue and Lawndale Avenue and Mayfair Shafts and about 22,000 feet of 12-ft. tunnel, including all shafts and suction tunnels at the Mayfair Pumping Station site.

The general policy of the then city administration being to do all city work possible by day labor, it was recommended that the greater portion of this tunnel be so constructed. It was, however, decided to let Section One by contract on account of the crib and the necessity of lake equipment which the city did not possess nor desire to acquire. Bids for this section were received December 2, 1914, and the work is now progressing.

The crib is of a new and entirely different design from any previously constructed, and a few remarks relative to the same may not be amiss before proceeding with the main purpose of this paper, to describe the day labor construction.

All previous cribs constructed by the City of Chicago in recent

years had solid timber bottoms about 6 feet thick, with the timber work extending to a height of about 24 feet from the annular rings surrounding the center well, to the top of which concentric steel shells were attached extending to a height of about 40 feet or to an elevation of about 8 feet above the surface of the water. The space between the concentric steel shells over the timber work on the cribs formerly constructed was then filled with concrete. A parapet wall, faced with granite and backed with concrete, was then extended for another 20 feet above the steel shells. The center well was then covered with a building and living quarters arranged on the available space outside thereof.

The bottoms of these cribs were made of wood in order that the same might be floated into place and sunk. The construction always placed the center of gravity of the crib rather high above the bed of the lake on account of the great amount of lighter material held in place by the masonry and steel work above, tending to make the crib topheavy and to rock considerably during severe storms.

With this type of crib it was always difficult to sink the intake shaft on account of the necessity of cutting through the solid timber bottom before encountering the bed of the lake.

The price of timber having advanced quite considerably in recent years and the cost of steel and concrete having declined, attention was turned to the idea of constructing a crib with only steel and concrete.

The final plans for the Wilson Avenue Crib resulted in a design of two concentric steel shells, the outer shell being 3/8 in. thick and 90 ft. in diameter and the inner shell 40 feet in diameter. These two shells are held together by intermediate bracings and the intake ports.

By correct calculations with the ports bulkheaded and intermediate flotation chambers attached to the bracing, a sufficient buoyancy was obtained to float these steel shells the same as a vessel.

The steel shells had cutting edges on the bottom in order that the crib might seal itself into the bed of the lake, thus permitting the pumping out of the intermediate well when the work of sinking the shaft should start.

There is, however, one departure in the design of the intake shaft; that is, to do away with the gates and the part of the cast iron cylinders extending above the surface of the lake. The present design provides for the top of the shaft to be about 10 feet below the surface of the water leaving the entire area of the upper part of the shaft free for fish screens.

The Construction Division of the Bureau of Engineering after constructing some smaller but difficult clay tunnels during the previous two years and after the completion of the borings was given authority in September, 1913, to sink the shore shaft of the Wilson Avenue Tunnel and to construct a short piece of tunnel either way therefrom.

Shortly afterwards, authority was given for the construction by day labor of Section III, it being concluded that Section II, the long

lake section, was too large a job to entrust to this method of handling. This, of course, resulted in the constructing of only a temporary plant for the sinking of the shore shaft and a careful study of the required plant for the land portion.

When the bids for Section II were received and opened in June, 1914, the Commissioner of Public Works and City Council decided to reject them all and to permit the Construction Division to build this portion by day labor also.

The first work on Section III was begun at the Mayfair pumping station site on the screen shafts during April, 1914. Actual mining in the rock tunnel began on December 22, 1914, and the connection between Mayfair and Lawndale drifts was holed through on December 15, 1915. The suction tunnel for the pumping station was also completed during this time.

The work at the Lincoln Avenue Shaft was started during May, 1914, and at the Lawndale Avenue Shaft during September, 1914.

All work on Section III will undoubtedly be completed by February, 1917.

The time limit on Section II is 42 months from September, 1914, or March, 1918. The work will undoubtedly be completed by March, 1917, or one year ahead of schedule.

The time limit on Section I is 40 months from January, 1915, or May, 1918. This should also be bettered if nothing unforeseen happens.

The day labor construction of this tunnel, with which this paper has principally to deal, naturally resolves itself into four major divisions, which will be taken up in consecutive order:

I. Organization.
II. Plant.
III. Method of Tunneling.
IV. Disposal of Excavated Material.

I. ORGANIZATION.

All the work is under the general direction of the Commissioner of Public Works. The work was planned and is being executed by the City Engineer, reporting directly to the Commissioner of Public Works. The Engineer of Water Works Construction is immediately in charge of the Construction Division of the Bureau of Engineering, and reports directly to the City Engineer and is the general superintendent, as it were, of the construction of this plant and tunnel, as well as other construction work done for the water works of the City of Chicago.

After the above, at each shaft of the tunnel, the standard organization of the Construction Division is followed, namely:

An Assistant Engineer, who is in local charge of the work.

Reporting to the Assistant Engineer is the tunnel foreman, who has general charge of all the labor and upon whose experience as a miner the Assistant Engineer naturally relies more or less.

The drilling and blasting of the heading is in charge of a heading boss who reports directly to the tunnel foreman. The miners who operate the drills and load and explode the charges placed in the borings or holes, together with their helpers, are under the immediate jurisdiction of the heading boss.

The muckers working in the heading load the blasted rock into cars and are under the direction of a mucking boss who also reports directly to the tunnel foreman, but, of course, works in harmony with the heading boss during the period when both are engaged in the heading.

The concrete gang, who handles the concreting apparatus and the moving of concrete forms, is under a concrete foreman who reports directly to the tunnel foreman.

A small track gang, supervised by a "straw-boss," keeps the track in shape, and reports directly to the tunnel foreman.

Other unattached labor, such as top laborers and pumpmen, report directly to the tunnel foreman.

The hoisting engineers, who operate the hoists and have charge of the power plants at each shaft, also report directly to the tunnel foreman.

II. PLANT.

Headhouses and Trestles: The headhouses and trestles were constructed to conform to the needs of the various locations, at some places where enough room was available high headhouses and trestles were constructed so that all muck might be stored during construction; at others, the structures were built only high enough to dump into bins from which the stone was removed daily. The average height of the trestles was about 40 feet to the top sheave.

Machine House: The machinery houses were built where possible to contain the hoists, three or four high pressure air compressors and two blowers on the first floor, while it was found to be most satisfactory to locate the men's quarters on the second floor of these buildings. These quarters contained separate rooms for the foremen, lockers for the men, benches on which to dress, steam coils for heating the room and drying clothes, and toilets and shower bath facilities.

Blacksmith Shop: Each shaft had its blacksmith shop for sharpening and repairing tools and minor machinery repairs.

Cement Warehouse: A cement warehouse, capable of holding 1½ carloads of cement, was erected at each shaft.

Tool and Stock House: A tool and stock house was built, sometimes independently, and sometimes in connection with the blacksmith shop.

Magazine: A powder magazine, built according to city ordinances governing such structures, was placed as much isolated from the other buildings as the limited space would permit; one was also built near each shaft in the tunnel.

Office: An office for the use of the engineer in charge of the

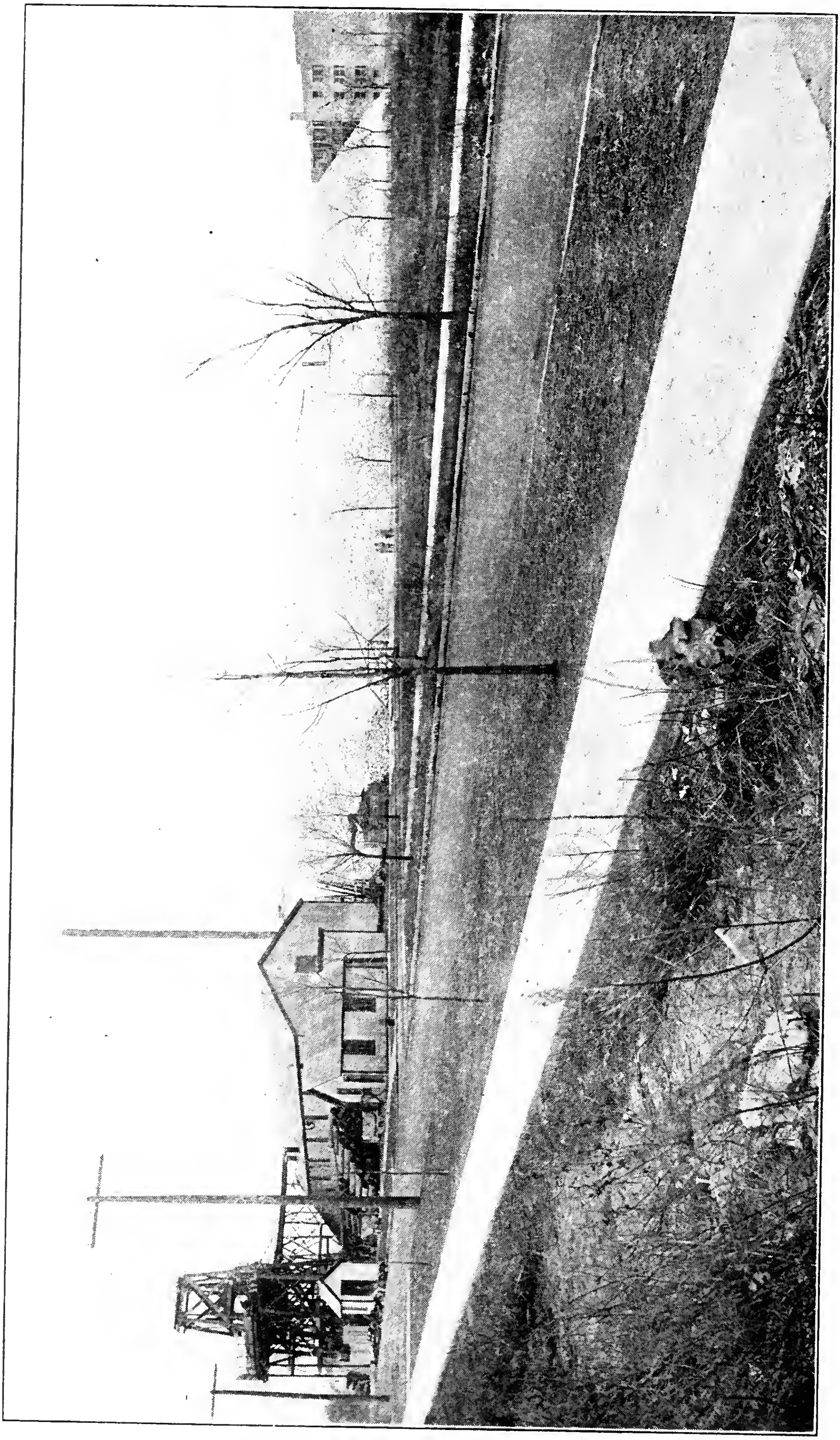


Fig. 1. Typical view showing construction plant and rock pile at each shaft.

shaft and his engineering and clerical force was placed near the entrance of the yards which was fenced in to decrease the liability of accidents and annoyance by idle bystanders.

Power: The power used at all shafts is 220 volt alternating electric current, supplied by the Commonwealth Edison Co. (under their contract Form C-3), who placed transformers to furnish as much as 800 H. P. at one location. The average cost of the current is about 1.3c per kw.-hr.

Hoists: The hoists used are 32 in. x 24 in. single drum Thomas Elevator Co.'s electric hoists, driven by 50 h. p. slip-ring continuous rating motors. The hoisting speed was set at 200 ft. per minute for a load of 5,000 lbs. At the time of greatest progress the hoists proved to be working well over their capacities, and it seems possible that still better results could be obtained by adopting the double skip method of handling the hoisting problem. The hoisting was all done on two parts of line, and 30-inch, self-lubricating sheaves proved the most satisfactory for this work. The hoisting cable is a ¾-in. 6-19 special plow steel cable. The cost of the hoists was $1,600.00 each. An extra motor is held in reserve to replace any motor suddenly disabled.

Air Compressors: Compressed air for operating air drills and concrete mixer and placing equipment is supplied by three or four Ingersoll-Rand Imperial compressors each of a capacity of 600 cu. ft. of free air per minute, delivering air at a normal pressure of 110 lbs. and operating at a speed of 190 r. p. m. From the compressors, the air travels through a 7-in. header to a receiver 4 feet in diameter and 12 feet high. From the receiver, a 6-in pipe line drops down the shaft and thence branches to 4-in lines in the short drifts. The high pressure air line is 6 in. in the long drift under the lake. The cost of each compressor was $2,383.50, and of the receiver $144.00. They are being operated by 100 h. p. continuous rated motors.

Rock Drills: The rock drill question was given considerable study, and after securing all available information both as to what had been done in Chicago and what had been accomplished in other parts of the country since the last rock tunnel was completed in Chicago, the decision was arrived at that, the best way to determine which is the most efficient type and make of drill for any particular rock formation was to equip each shaft with a distinct type of rock drill. Accordingly, the old piston type of drill, the water piston type and the water hammer type, were used in the work. The results found up to Jan. 1, 1916, were that the most economical type of drill from the standpoint of repair parts is the piston; the fastest drill is the water hammer drill, but the difference between the drills is not marked in either comparison. The hammer drill, however, uses less air than the piston drill. The specifications called for drills with not less than 2⅝ in. cylinder diameter and a capacity of 10-ft. holes. The cost of the better grade of piston drill of this size is $193.00; of the water

piston drill, $229.60; and of the hammer water drill, $280.00—all equipped complete with a 50-ft. length of hose.

Method of Mounting Drills: Both the column and heading bar method of mounting the drills at the face were tried and the advantage thus far seems to rest with the column method. Bench holes were drilled from the column or bar as much as possible. An interesting feature of what are called "water drills" is the hollow steel used with this make. Through a small bore in the center of the steel a stream of water and air is continually directed against the face of the rock, washing out the pulverized rock and constantly exposing a clean surface to strike against, thus preventing the "cushioning" of the blow in the powdered rock.

Drill Sharpening: After the tunnel work had advanced for some time, it was found advisable to install a machine to form and sharpen the drill steels. A No. 5 Ingersoll-Rand Leyner drill sharpener was purchased with the necessary dies, dollies, etc. This machine, which is operated by compressed air, holds and forges the steel. The cost of the machine, with all applicances, was $1,379.55. It is operated by one man and easily performs the work of four blacksmiths and does the work better. As a detail of interest, I might add for those not familiar with this class of work that the best results are obtained when the cutting edges of the points or wings in a drill steel lie in the same plane at right angles to the axis of the steel and in this feature the machine sharpening naturally far exceeds the hand work.

Track: To transport the muck from the heading to the shaft double track was laid in the tunnel. The track was composed of 20-lb. rail laid at a 24 in. gauge on steel ties. The steel ties proved economical and efficient. It requires about 2 wooden ties to every 20 feet of track length to keep the steel ties from creeping and forcing the track out of alignment.

Dump Cars: Three hundred steel side dump cars, of one cubic yard capacity each, were purchased. The cars are of especially rugged construction, which was demonstrated when one tumbled from a 50 ft. dump without any preceptible damage, and again, when through some unaccountable oversight an empty car was dropped down the shaft and only required minor repairs to make it as good as new. The cars are supplied with roller bearings and half-size automatic couplers. They cost $85.00 each, and were purchased from The Kilbourne & Jacobs Mfg. Co., of Columbus, Ohio.

Gasoline Locomotives: After the drifts had been advanced to where mule hauling became rather slow and expensive gasoline locomotives were installed. They are of the four wheel type, driven by 40 h. p. four-cycle, four-cylinder engines running at 800 r. p. m. The locomotives weigh 5 tons each, and can attain a speed of 8 miles per hour and at that speed develop a draw-bar pull of 900 lbs. They have proved entirely satisfactory. They usually pull trains of 20 to 25 loaded cars, and in an emergency

as many as 57 loaded cars were pulled out of the drift. The exhaust gases thrown off by the internal combustion engines were passed through a water-box which removes the smoke and unburned gasoline. The small quantity of CO and CO_2 remaining is ordinarily sufficiently diluted to be unobjectionable.

Fig. 2. Completed side walls and arch, locomotive and train of cars, drainage ditch and general track layout.

Gasoline locomotives have been used in other tunnels with unsatisfactory results, but this appears to be due to the mechanical defects in construction. The demand for these locomotives has heretofore been limited, and this probably accounts for the fact

that this type of machine has not been perfected to the extent that automobiles have been. The locomotives were furnished by The Baldwin Locomotive Works, at a cost of $3,100 each, and have proved satisfactory in operation, although our experience indicates some minor changes in design would improve their operation.

Pumps: The drainage of the tunnel is being taken care of by electrically driven direct-connected centrifugal pumps. Two sizes of pumps are used, one of 1,000 gallons capacity, and the other of 300 gallons capacity, to work against heads of approximately 150 feet. The first type is driven by 75 h. p., and the second by a 20 h. p. motor. The motors are of the squirrel-cage induction type with impregnated moisture-proof windings. The 1,000 gallon type pumps were furnished by the Lea-Courtney Co., at a cost of $983.00 each, while the 300 gallon type pumps were furnished by the Yeomans Bros. Co., at a price of $341.00 each.

Ventilating System: Great care was exercised in the design and installation of the ventilating system in the tunnel and a quantity of air much in excess of any heretofore used in similar work was provided. The standard equipment consisted of one General Elecrtic centrifugal air compressor, of a capacity of 5,000 cu. ft. of air per minute for each drift, at a pressure of 1.5 lbs. where the length of the drift does not exceed 6,000 feet. Where the drifts are longer, two compressors are used in series, giving a capacity of 5,000 cu. ft. at 3 pounds pressure. These compressors are driven by 50 h. p. motors, operating at 3,600 r. p. m., and directly connected to the centrifugal impeller. Gauge boards upon which are mounted indicating and recording instruments were provided so that an absolute check can be maintained upon their operation. These compressors were furnished by Wm. A. Pope, at a price of $1,398.00 each. Steel asphalt coated pipe, 18 inches in diameter, delivers this air to the face.

This pipe is made of No. 14 gauge steel in 20 ft. lengths with ends flanged back at right angles to axis of pipe and provided with loose malleable iron flanges. A soft rubber gasket is inserted between two lengths and the joint then tightened up as in a Van-Stone of Crane lap steam pipe. The unusual point of this pipe is its light weight—two men easily lifting a 20-ft. length—and its strength. The pressure on a 20-foot length when fans are exhausting is about 20 tons. The end of the pipe is maintained about 100 ft. from the bench.

The pipe is suspended along the side of the tunnel over the drainage ditch. The system can be operated equally well to blow in or exhaust air from the tunnel. After a blast, the system is reversed, and the powder smoke removed from the tunnel. This reversal is accomplished by a by-pass with the necessary valves, the compressor always blowing in one direction. When the air is being forced into the tunnel in the winter the air is heated in order not to chill the men working.

Concrete Handling Machine: This apparatus consists of:

1. An inclined track on which the car loaded with rock is elevated by means of a 10 h. p. electric hoist located on the platform.

2. An inclined screen consisting of a steel plate perforated

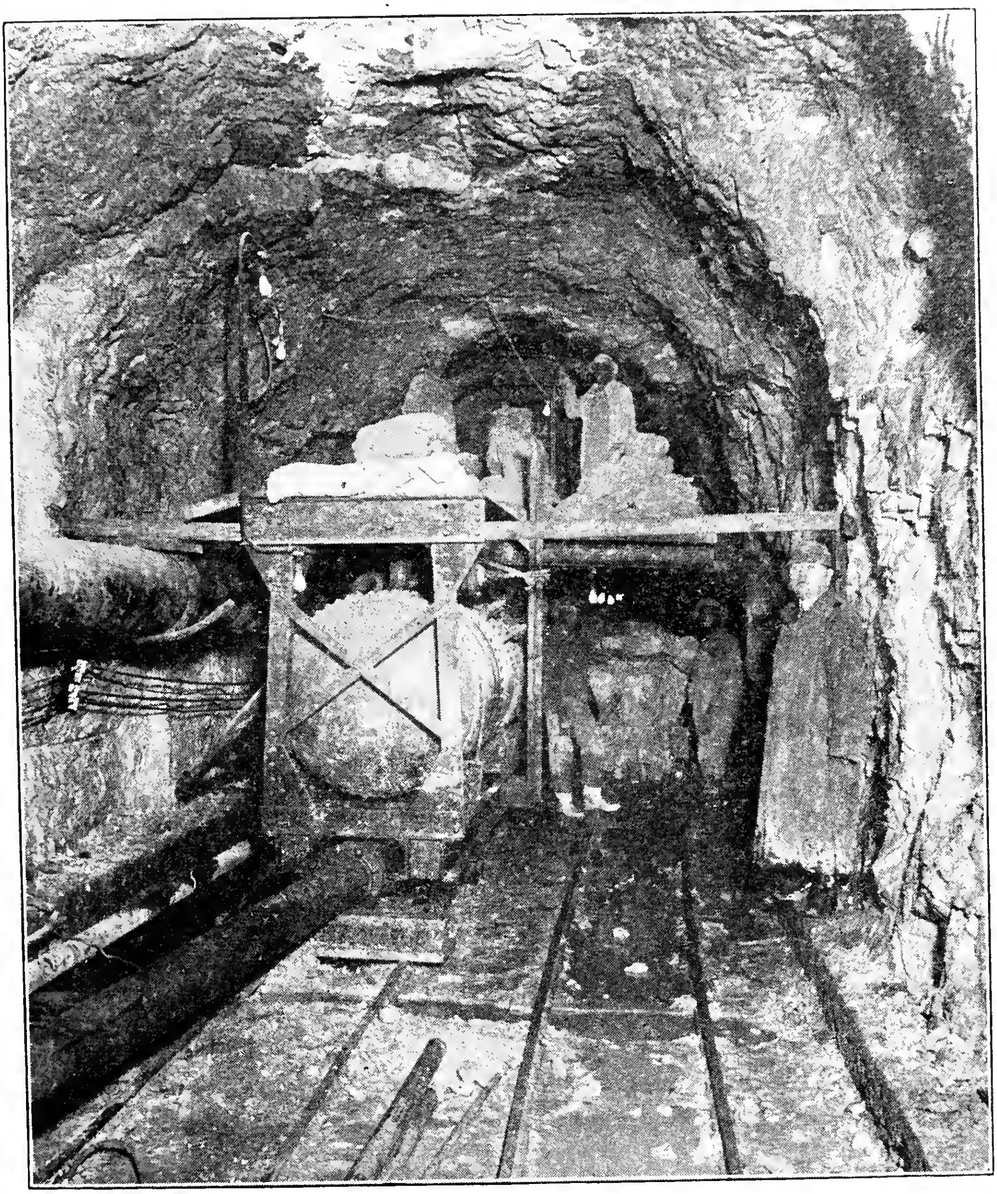


Fig. 3. Rear end of concrete mixer and air tanks, showing 8-inch pipe through which mixed concrete is shot to the forms.

with 4 in. diameter holes on which the contents of the cars are dumped.

3. A conveyor belt which carries the stone to the mixer hopper. This belt is driven by a 3 h. p. electric motor at a speed of about 150 ft. per minute.

4. A structural steel frame work mounted on wheels carrying the first three items and also containing a platform for the engineer operating the hoist and belt motor.

5. The pneumatic concrete mixer.

6. Two reserve air tanks, of 14 cu. ft. capacity, to prevent sudden drops of pressure in the air supply line, due to the large volume of air required for each operation of the mixer.

7. A structural steel framework mounted on wheels carrying the air tanks and mixer and providing a working platform on which cement is stored and the mixer hopper is carried.

From the mixer an 8-inch steel pipe carries the concrete to the forms. The screening and mixing apparatus is moved every 12 days a distance of 700 feet. As the forms approach the mixer the 8-inch pipe is shortened until another moving of the mixing apparatus becomes necessary.

The screening and mixing outfits, exclusive of the mixer, were constructed from the City design by the Stephens-Adamson Mfg. Co., of Aurora, Ill., at a cost of $3,170 each. The concrete mixer is leased from the Concrete Mixing & Placing Co., of Chicago, Ill. The operation of this machine will be described later.

Tunnel Forms: For the 12 and 13 ft. tunnel it was decided to employ the traveling type of forms. The controlling feature in the design of these forms was the fact that mining and lining had to be carried on at the same time, so that room had to be provided through the forms for transportation of muck from the face to the shaft. The forms were especially designed for this purpose, and to suit the clearances required by the dump cars and locomotives. The forms are constructed of structural shapes and steel plates in 30 ft. sections and are mounted on roller-bearing wheels running on 70-lb rail laid ahead of the work.

The forms were furnished by the Blaw Steel Construction Co., of Pittsburgh, Pa., at a rental of $40.00 per lin. ft. of form.

III. METHOD OF TUNNELING.

The top 20 feet of the soil at the Shore Shaft is sand, 12 to 14 feet of which is water-bearing; under this is soft blue clay gradually growing harder until the rock surface is reached. On account of the water-bearing sand, it was decided to sink a ⅜ in. steel shell to a seal in the clay so as to effectually shut off all possible leaks into the shaft.

The excavation was accordingly started with an 18-ft. square set of bracing and sheeting inside of which the steel shell was started. The shell, 13 ft. 6 ins. in diameter, was brought on the job in five 6-ft. sections, 30 feet in all, and riveted and caulked, section by section, and sunk into place by digging in the center and loading the shell with 140 tons of pig iron. The interior of the shell was braced with octagonal bracing to insure stiffness. Below the shell wood lagging, with standard caisson rings, was used to the rock surface. When rock was reached, the shaft was

concreted to the top. Both wood and steel forms were used, each being equally satisfactory. All shafts were sunk in this way except that only the Shore Shaft required a steel shell.

Mining: In order to obtain positive information as to which method of tunneling was the most economical, speedy and best

Fig. 4. Steel forms on travelers, and position of 8-inch concreting pipe during concreting operations.

adapted to local conditions in Chicago, it was decided to try out a number of different methods of mining.

Accordingly, the standard method of top heading and bench, operating on the two-shift basis, was used at the Shore Shaft and the Lincoln Avenue and the Lawndale Avenue Shafts.

These shafts were selected for the two-shift method on ac-

count of the territory being more or less built up and the necessity for inconveniencing the rest of the community as little as possible.

This method involves the drilling of from 28 to 34 holes in the heading and 8 to12 holes in the bench. The cut holes are from

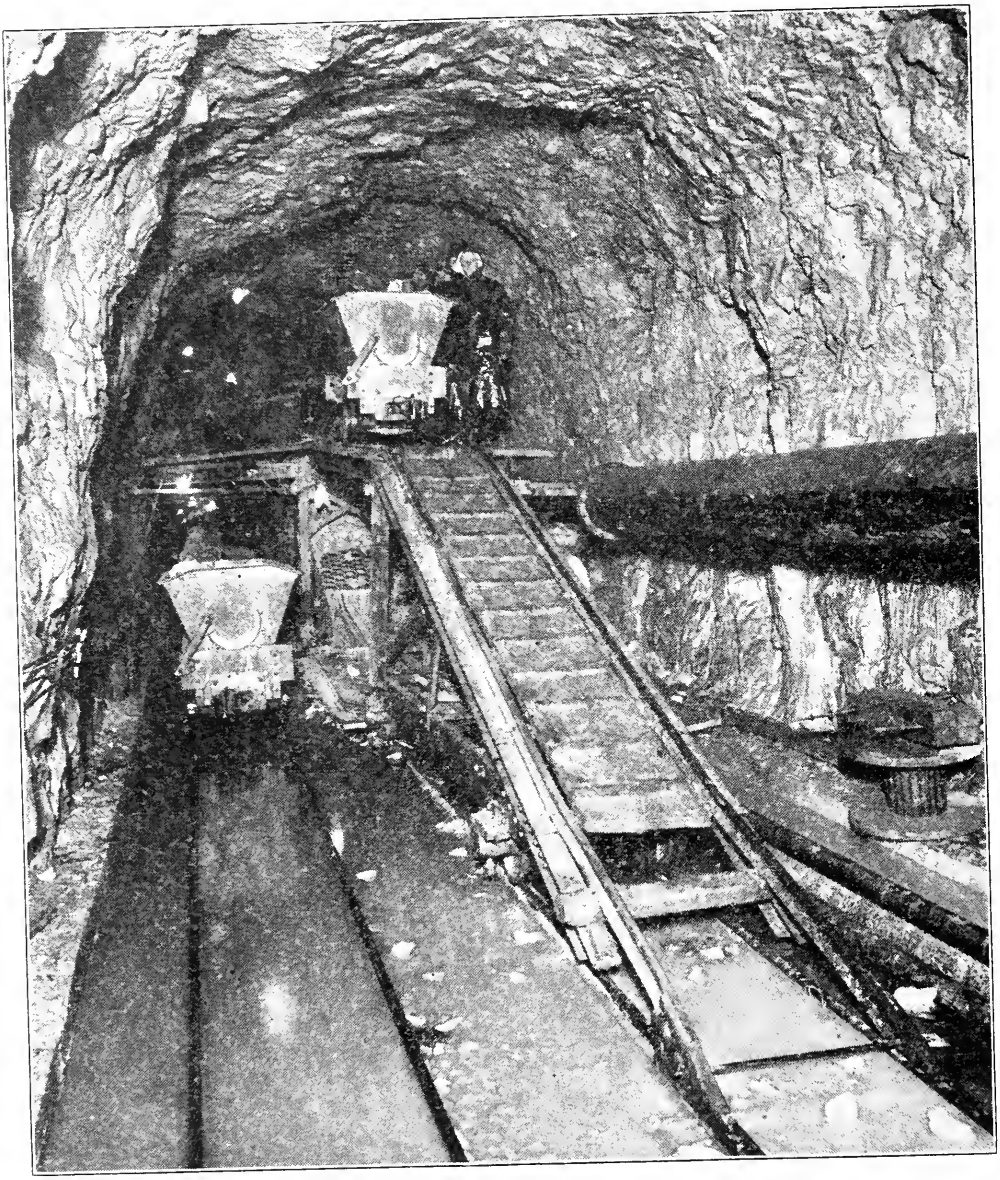


Fig. 5. Incline track at front end of screening machine. Note inclined screen through which the rock for concreting passes.

12 to 14 ft. deep and we had some 15 ft. steel made up in order to still increase our shot.

The bottom heading method with breakdown roof, on the 3-shift basis, was used in the single heading from the Mayfair Shaft. This territory was not so built up, and it was found that no complaints resulted from the blasting operations carried on during all

hours of the day and night. This method involves the drilling of about 23 holes in the bottom heading and 5 holes in the roof heading. The cut holes are from 9 ft. to 10 ft. deep.

At the latter shaft an experimental shooting platform was constructed for the purpose of intercepting the rock shot down from the roof, thus avoiding blocking the free passageway to the bottom heading for a certain time, while the rock from the roof was being mucked out. The platform was constructed of steel and lasted but a short time, finally becoming so badly bent as to make it of no further use. Mention is made of this shooting platform for the reason that it is the writer's belief that no such device, however constructed, will ever ultimately pay in work of this kind.

Standard Crew—Mining and Mucking: In general, it may be stated that our experience has shown that the top heading and bench method is the most economical for this rock, operated on the two-shift basis. The reason for this is two-fold: In the first place, if there is any quantity of water, this permits of the free escape of the water instead of being blocked by the breakdown shot of the top heading; the second and most important reason is that on the two-shift basis a certain task can be given to the gang which must be completed before they leave the work. In other words, it is the duty of the miners to set up columns, drill and load their holes, and shoot their rounds before going home. Likewise, it is the duty of the muckers to muck out all the rock from the previous shift. It is understood that the time of the shift ends whenever these tasks are completed.

With a well-organized crew, for a 10 ft. to 12 ft. round, the muckers will complete their work in from 6½ hours to 7 hours and the miners in from 7 hours to 7½ hours. If the gang is not up to standard, it may take them 9 hours to 10 hours for which they only receive one day's pay. The fact that a shift can be held responsible for a definite amount of work spurs each man on to do his part.

In the three-shift method, the gang only works eight hours and quits, the succeeding shift taking up the work where the previous shift left off.

If, for any reason, the previous gang neglected their work it is very much harder to place this responsibility without argument and question. This latter fact is of extreme importance, in operating, as we do, under the civil service system, because absolute evidence must be forthcoming before a man can be discharged.

Experience also showed that the total daily progress was not any greater by the three-shift than by the two-shift method, although a greater number of men were working with the three-shift method.

As an example of the increasing progress of this work, it may be stated that the best average daily excavation done by contract on a 12-ft tunnel in Chicago was about 8 feet per 24 hours. On the Southwest Land and Lake Tunnel a progress of 15 feet per day was made, but the excavation required so much trimming sub-

sequently that the actual daily progress was very much less than 15 feet. The average daily excavation performed by the city, by the day labor method, is about 20 feet, many days being as high as 22 and 23 feet. The maximum obtained has been about 26 feet.

When excavating rock at this rate a round trip of cage would be made every 56 seconds, 7 seconds being used each at top and bottom for loading a car. The descent would be made in 10 seconds. The bottom of shaft at Lincoln avenue, in order to facilitate

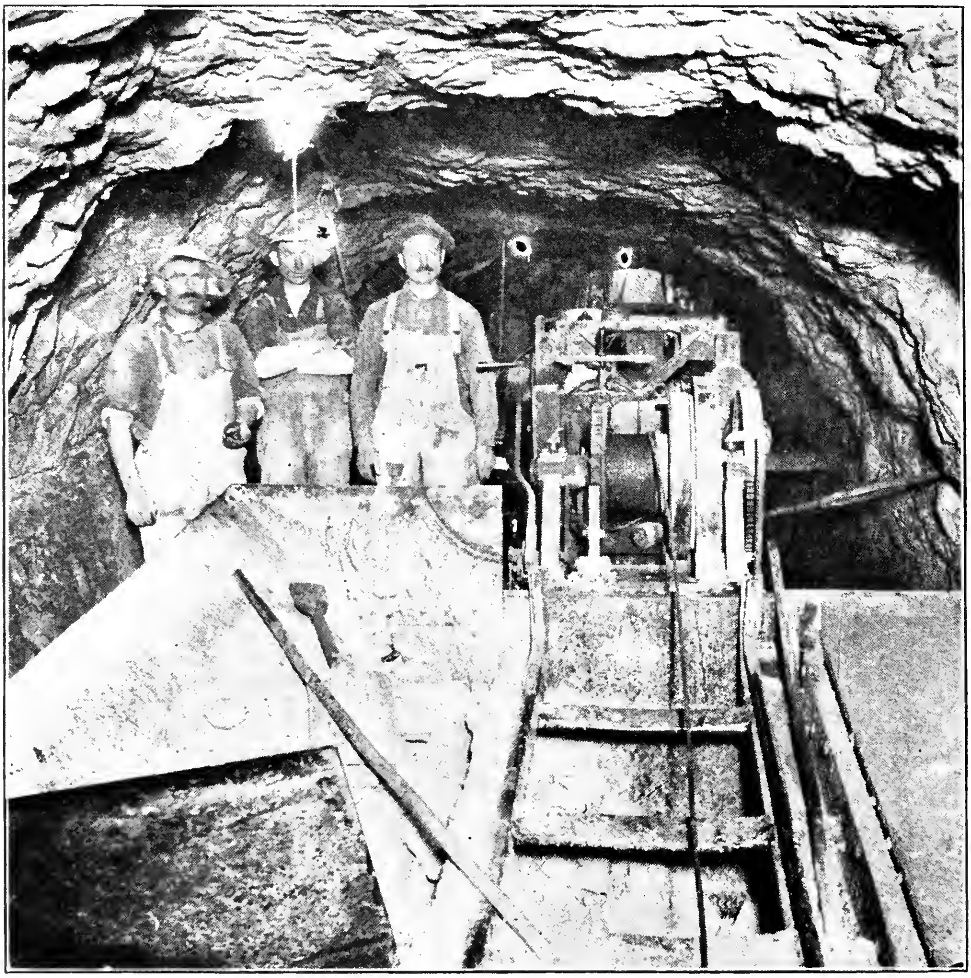


Fig. 6. Hopper on screening machine into which mine cars are dumped.

this operation, has a spare track on one side of cage to handle empty cars.

Several wide faults were found in the rock necessitating timbering and bracing or concreting as fast as the same was mined. The first instance encountered was at Lincoln avenue, and here wooden and light steel forms were used, using hand-mixed concrete of mine-run rock with 1½ bbls. of cement to the yard. The strength of the mixture is remarkable. The concrete after setting sixteen

hours would be blasted against without injury. This, however, ruined the forms.

Concreting: After having organized the mining into satisfactory shape, serious attention was then given to the lining of the tunnel.

The usual method previously employed by contractors in lining tunnels of this size was to excavate the drift completely previous to starting the lining of the tunnel, bringing all material to the surface where it was stored or otherwise disposed of to the best advantage. After the mining was completed, the excavated rock stored on the surface was crushed and screened, mixed with sand and cement and brought into the tunnel and placed by hand behind forms of steel or wood. From 30 to 35 feet per day were lined in this way. When the drift was long, the concrete sometimes had its initial set before arriving at the forms.

This method of handling was necessary on account of the restricted space, making it impossible to carry on both operations of mining and lining in the same heading at the same time. This also operated to extend the ultimate time for completion on account of having to line the entire drifts after all mining was completed.

It was noticed in the Wilson Avenue Tunnel that the rock in the mine run condition contained considerable fine material and would make apparently good concrete. Various compressor foundations and other miscellaneous concrete work on top was made with this material showing excellent results. Test cubes, 18 in all, were made with various proportions of cement, aged 30 days, and broken at the Armour Institute of Technology. These indicated that the concrete was of satisfactory strength and that the material was entirely adapted for concreting.

Realizing the possibilities not only of completing the work very much earlier, but of saving the expense of hauling back and forth the material required for the lining, as well as the cost of purchasing crushed stone and sand for the concrete, it occurred to us that a method could be devised which would line the tunnel with the mine run rock in the same drift as the mining was carried on, thus carrying on both operations simultaneously.

After considerable thought and study, a scheme was worked out which would accomplish this purpose. This consists of a screening and loading machine which handles all the rock coming from the heading, permitting the material less than 4 inches in dimension to be deposited in the hopper over a pneumatic mixer. The oversize is rejected and loaded by hand into a car standing nearby.

The pneumatic mixer deposits the concrete through an 8-inch pipe placed behind the steel forms at a distance of as much as 800 feet away.

The screening machine and the concrete mixer are designed to run on roller-bearing wheels operating on one track and within the clearance of the final tunnel dimensions. The concrete forms are

made of steel operating on a traveler on roller-bearing wheels which can readily be moved.

By means of this system approximately 60 feet of forms are lined in two shifts with 60 feet of concrete forms, the concrete only setting about 16 hours before the forms are removed. The clearance on the forms and the concrete machinery is so arranged as to permit of unhampered operation of the trains through and past the concreting.

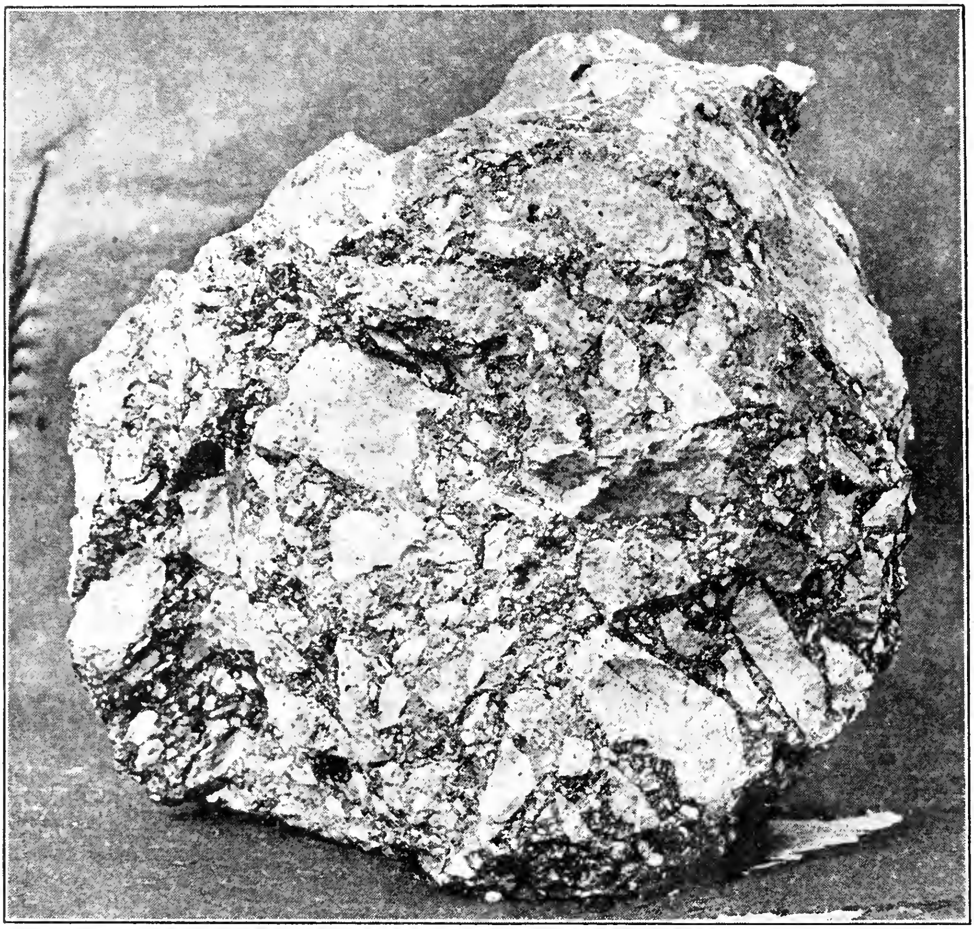


Fig. 7. Mine-run concrete, such as had been cut out of the lining for inspection.

The net results of this method of handling are that between 20 to 22 ft. a day is mined and approximately 60 feet of tunnel is lined with the excavated material on each working day in each drift.

In advance of the steel forms, guide walls are constructed by hand concreting. These walls are made of wooden forms set to the true line and grade from the engineer's centerline and grade plugs. These walls guide the steel forms so that the finished lining is absolutely true to line and grade. This is something that it

was difficult to get a contractor to do, his policy being rather to fit the hole as blasted as near as possible, and thus avoid trimming. This would sometimes result in the tunnel being a series of short tangents varying anywhere from 2 in. to 6 in. from a straight line.

Rock Crushing Plant: At the Lawndale Shaft, the connection between Mayfair and Lawndale being made and there being only sufficient unmined rock left between Lawndale and Lincoln to equal

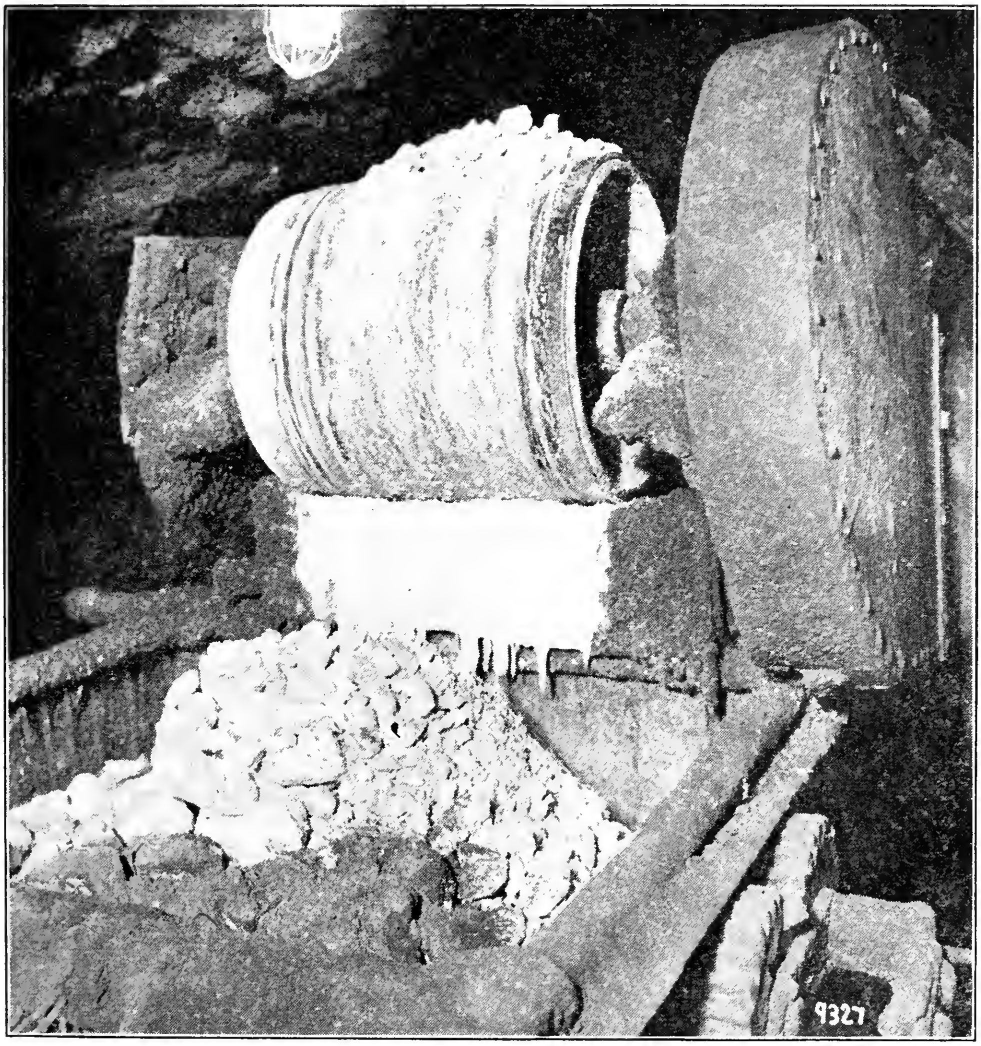


Fig. 8. Top of incline conveyor and hopper over pneumatic concrete mixer; water and cement are added at this point before the charge is deposited into pneumatic mixer.

that required for the entire distance between Lincoln and Mayfair and, further, because the rock is of a different texture, it was decided to put in a rock crusher at the bottom of the Lawndale Shaft. In these drifts approximately 50% of the total muck from the face is over 4 in. in dimension. Accordingly, a concreting machine is placed between the face and the Lawndale Shaft; another is

placed between Lawndale and Mayfair. The over size from the east machine is put through the crusher and ultimately is put in place at the west machine.

Local Tunnels at Pumping Station: The methods used in constructing the suction tunnels leading from the main supply tunnel to the pumping station are also somewhat interesting. The 8-ft. tunnels leading from the east gate shaft to the two screen shafts were excavated in clay in the usual method. The clay being hard, about 6 feet were mined and concreted per shift. The suction tunnel in the building is subjected to great pressure from the adjoining foundation walls of the pump room and heavy pump foundations. For this and the added reason that better progress and a certain saving can be made if the mining and lining operations could each be carried on continuous, instead of alternating, as is customary, tunnel lining plates were employed in this part of the tunnel system. These plates form a continuous steel shell of the outside diameter of the tunnel and the lining can be deferred until the entire tunnel is excavated. The location of the tunnel made very heavy reinforcing necessary and this too could be much more advantageously handled in a completed bore than in the usual crowded conditions resulting from alternate mining and lining. The plates were furnished by the Blaw Steel Construction Co., of Pittsburgh, Pa., for the price of $2,413.00 for a total of 274 lin. ft. of tunnel.

IV. DISPOSAL OF EXCAVATED MATERIAL.

The question of disposing the excavated material was a rather serious one, particularly at the Shore Shaft where no available space for storage purposes was to be had.

After considerable effort the City was finally able to make a contract with the Peoples Crushed Stone Co., who agreed to take the stone away as fast as produced from the Shore Shaft and to remove the rock piled at the other shafts within a reasonable time after the completion of all the work.

The contract provided that crushed stone for the lining of the tunnel should be furnished to the City upon requisition from time to time.

The City was very glad to be able to make this contract inasmuch as it was relieved of a considerable expense in the removal of such a large quantity of excavated material, totaling something over 400,000 cu. yds. The company erected at Montrose Ave. and the River a crushing and washing plant capable of handling between 750 to 1,000 cu. yds. per day of 10 hours.

The plant consists of No. 7½ giratory crusher with concaves set to pass a 3½ inch product. From this crusher, a No. 8 continuous bucket elevator on 85 ft. centers, elevates the crushed material to the top of the plant at which point 500 gallons of water per minute is introduced by means of a centrifugal pump. The screening plant consists of two sets of conical screens located side by

side, four in a row, one slightly lower than the other. The first screens are perforated with 2½ inch holes, the second with 1½ inch holes, the third with ¾ inch holes, and the fourth with 5/16 inch holes.

From these screens to bins below of 500 cu. yds. capacity, the stone is stored ready for loading into trucks or wagons for the market. The over-size from the first screen passes through a No. 4 re-crusher with concaves set for 1½ inch product. The tailings from this crusher by means of a belt conveyor is transported to the main or No. 8 conveyor and re-elevated back to the screening plant. Under the bins a horizontal belt conveyor will transfer the product of any bin to an inclined conveyor at the rear for piling and storage purposes.

The tailings from 5/16 inch screen are carried to a settling bin consisting of a V-shaped trough at the bottom of which two inclined 12 inch screw conveyors running at about 20 revolutions per minute elevate the fine material into a storage bin, the water running down the screw by gravity into the settling basins below from which the centrifugal pump furnishing all the water to the plant receives its supply.

The stone crushed by this plant and the screenings are sold in the open market in competition with stone and gravel and torpedo sand.

Inasmuch as only one of the shafts, namely, the Mayfair Shaft, is located on a railroad, all the excavated rock is removed from the various shafts by means of 7½ ton auto trucks having a capacity of 4 cu. yds. of mine run or 5 cu. yds. of the crushed material.

The average time required to load and unload a truck is 15 minutes and the speed on the road with average about 10 miles per hour.

The crushing plant cost in the neighborhood of $50,000.00, and the standard price for the material at the bin is $1.00 per cubic yard or $1.50 per cu. yd. delivered within a radius of three miles of the plant.

DISCUSSION.

John Ericson, M. W. S. E.: I would like to add a few words to what Mr. Clausen has said about his work.

I have been more or less intimately connected with tunnel construction in Chicago for some twenty-five or thirty years, and practically all of our tunnels heretofore have been constructed by contractors under the contract system. When we contemplated the Wilson Avenue tunnel there was really no intention to undertake such a work by day labor, but we prepared specifications and advertised for bids for this work. There were five or six bids received, and after having considered them carefully, we came to the conclusion that it would be to the best interest of the City of Chicago to reject all bids and recommend the building of this tunnel by day

labor. When the city engineer made this recommendation he fully realized that he laid upon himself a tremendous responsibility, because it is well known that whatever creditable things one may do in working for the City of Chicago the public will hear very little of it. If one makes any mistake whatever, you can be sure one will hear of it and be censured repeatedly. So there was really nothing much to gain personally except the satisfaction to one's conscience that one had done the best thing for the city.

I feel that we can be justly proud of our work so far in the prosecution of this big undertaking. It is also natural that the men who heretofore have become rich from contracts for just this kind of city work did not look upon our undertaking with any delight, but there is evidence that a good deal is being done to discredit our work and hamper us in our undertaking.

I take great pleasure in inviting as many of the members of the Western Society of Engineers as are interested in this work to visit our tunnel. I think Mr. Clausen will be very pleased to give you an opportunity to do so. If very many of you want to go he will have to take you in relays; he can not take you all at one time. But we shall be very pleased to have you visit this work and examine it thoroughly. Some day perhaps you may be able to be of some help to us if conditions should require it, and if you find us deserving.

Daniel W. Mead, M. W. S. E.: I appreciate fully what Mr. Ericson has said about the great responsibility that an engineer assumes in undertaking a work of this kind by day labor. It is a venture that I think an engineer should undertake only after a great deal of thought. As a general proposition, when work so undertaken goes right the engineer receives little credit, because that is the way it should go. If it goes wrong, no matter what happens, he is always blamed for the results. So as a rule when he undertakes such a venture, he is shouldering a tremendous responsibility, without very much hope of credit if he succeeds, except among the profession, and knowing very well that he will receive a great amount of criticism if anything occurs that adds to the expense or that can be criticised. Contractors naturally are opposed to having work done by day labor, and in the majority of cases it is inexpedient for an engineer to attempt to do public work by day labor. Here seems to be a piece of work where, as far as I can judge from what I have heard tonight, the method of day labor has been eminently successful.

No cost figures have been given, but I assume that the costs have been entirely satisfactory.

Mr. Clausen: I have here a copy of a statement which was given to the City Council for the work ending with December, 1915. This is the last report that is available.

This shows that a ten foot shaft complete, lined with concrete, costs $62.75 a foot; a twelve foot shaft, excavated in earth,

$49.09; excavated in rock, $64.09, and the lining $27.21. A completed twelve foot shaft, $118.83 per foot.

A thirteen foot shaft, $39.70 per foot, excavated in earth; in rock, $46.72 per foot; and lining for $21.41 per foot.

That was a shaft where we made an up-raise in the rock portion.

An eight foot tunnel in earth, which is that section that was mined out and lined with steel plates, as mentioned, is $38.48 per foot; and an eight foot tunnel in rock—those were those small stub drifts—$20.59 per foot for excavation.

The excavation of the twelve foot tunnel, including just the labor and materials, is $32.94 a foot; the estimated cost of the lining is $15.00 and we are going below that in the work we are doing.

The total cost per foot of all we did last year, including the depreciation on the plant and so on, is $41.88 a foot.

The total cost, including the lining, cleaning and so on, and the engineering inspection, for the work up to the end of last year, is $61.48 a foot. The estimated cost of constructing the tunnel by contract was $75 per foot, not including the engineering inspection or contingencies. In the one bid that was received in June, 1913, the specifications allowed certain unit prices for grouting and for drilling holes through the lining for grout pipes, etc.; in addition to the regular price per foot for the ordinary mining and lining, this unit price bid can not be considered as the final cost because the above mentioned extras provided for by the stipulated prices in the contract would also have to be added. Again, this price was for one long drift where only one plant would have to be erected and the total cost of it spread over the entire length of the drift under the lake. In this section, too, there would be very small chance for damage suits from damages to buildings and property along the line of the tunnel. The price bid, which was the lowest, was $60 per foot. That does not include any engineering or inspection. Adding on engineering and inspection and a few dollars for contingencies, such as grouting pipes and so on, the cost by contract would be $68.20 a foot, based on that low bid.

However, the bids varied considerably. The total estimated amount of the low bid was $1,242,630, and then they ranged from there up to $2,262,931.50. The high bid was by the same contractor who built section two of the Southwest Land Tunnel, which was the same kind of a tunnel which we are building here, and he evidently knew or thought he knew what it would cost, inasmuch as he had the previous experience. The average cost per foot of all the bids received was $78.38.

At the time when the bids were opened, all the other contractors agreed that the low bidder could not do the work for the price bid, and they also said that our time limit of forty-two months was entirely too short. One contractor said that it would be one of the biggest fall-downs the engineering department ever

had, namely, requirement of such a short time limit. We are going to beat our time limit by one year, at the rate that we are now going, so I do not think our judgment was so very bad.

Chairman DeBerard: Then, do I understand that the tunnel will be built for somewhere around $62 a foot, as it is being built?

Mr. Clausen: That, of course, depends upon the cost of dynamite. Dynamite has gone up since the first of the year about 120 per cent, and that is quite an item in cost of this work. That is an unforeseen contingency. If a contractor had the job he would probably go broke. That would be the answer, and that would still further delay our time of completion. So I cannot state.

John W. Mabbs, M. W. S. E.: Mr. Chairman, it seems to me that the Western Society as a body of engineers and the people of Chicago as a whole, should uphold the city engineers who have assumed this great responsibility and they should be most highly complimented for the work which they have so successfully and economically performed. It seems to me that they have worked along the right line. They undoubtedly have not gained any additional good will from the contractors, but they have performed a work which will be a lasting credit to them and a great benefit to the people of Chicago.

It is a certainty that contractors will not take a job unless they are reasonably sure of making money. They add enough to their estimated cost to provide for all possible contingencies and to allow a liberal margin for profit.

Usually, if there are unforeseen conditions that arise they are very apt to throw the additional expense back upon the city, so that in a great degree the city is compelled to assume more or less of the responsibility and the expense of contingencies.

There is no doubt that the city is able to secure engineers as competent as those employed by the contractors. There is also no doubt that these city engineers are able to accomplish the work as economically.

As has been shown here this evening, the city by so doing, is able to save the contingent expense, and the profit that the contractor is entitled to, which results in a greater saving to the tax payers.

Murray Blanchard, M. W. S. E.: I would like to ask a question about the condition of the concrete on the crown of the arch. I understand that it was put in by the concrete conveying machine, and would like to know what provision was made for grouting. Theoretically there would not be very much grouting required for such work. The claim is made for the conveying machine that it will shoot the concrete into the crown of the arch and pack it in solid. In general, in a neatly trimmed tunnel, it will do so. I had some experience with machine conveyed concrete a few years ago, in which a considerable number of grout pipes were used, and found that where the tunnel was roughly trimmed and downdrops of rock occurred in the roof the concreting was not always satisfactory.

While the forms would in all cases be covered with at least two or three inches of concrete, at the same time some of the material striking the downdrop would fall and pile up to the rock, forming a barrier that completely shut off the space beyond before it could be filled. I have tested the arch in such irregular rock sections (where the inspectors were alert in trying to prevent the bridging over) and found that the cavities sometimes existed, for the barriers form very rapidly and cannot be readily detected. Some of the arch tested had the appearance of being very good, but cavities would be found that would take a lot of grout. Where the pressure from the outside might be detrimental and damage the lining when the tunnel is empty, the matter of making provision for grouting is of considerable importance.

In the tunnel at Tallulah Falls, Georgia, the concrete was sometimes shot a thousand feet and, with one or two exceptions, at wet places, was all solid around the sides regardless of the regularity of the rock, but in the crown of the arch it was treacherous and apparently would be a good lining, while in reality it was not sound until grouted.

I would like to ask what provision was made to take care of such cases. Where much water percolated into the roof of the tunnel, I found this method of concreting the arch to be very unsatisfactory.

Mr. Clausen: In our experience so far the rock is very wet when it is mined and it gradually dries out. We try to hold off a little while until it is dried out before we go ahead with the concreting. Our experience so far shows that the arch is absolutely dry. There are very few places where the water comes through the wall. If any water comes through it comes in at the lower four or five feet on the side walls. We expect to drill some holes through the arch at intervals in order to actually test and see how far away the concrete is from the rock. We do not know positively. We have not tried. But there is no water coming through and the average thickness of the lining being at least twelve inches, we are not much worried, particularly as the lining is only supposed to be a finishing coat in order to make it smooth for the water to go through. However, that is what the unit prices for grouting, etc., were inserted in the specifications for, with the idea that we might possibly have to drill through and fill up some holes. In the side walls, where there are some leaks, we shall have to localize the leaks and put in bleeders and finally make it tight; but, on the whole, the tunnel is very dry. There are some few places to be fixed, but in the main it is very good.

Mr. Blanchard: My point was that there were places where the tunnel was absolutely dry, but on testing the concrete by tapping it with a bar, a hollow sound would indicate that there was a cavity. Breaking through such a place would sometimes reveal that there was only a surface coating of two or three inches of

concrete. The best way to insure a solid lining is to insert grout pipes as the concreting proceeds and to grout later.

Mr. Clausen: That can not be possible. What I have reference to is possibly a shrinking away from the rock an inch or two; I do not know about that. We have two men who stand at the end of this pipe and when it comes near the key, after every shot, they actually poke the concrete in and pack it with a stick in case it is not shot completely into place. So we know that it is in solid before the next batch goes in.

Chairman DeBerard: May I ask, Mr. Clausen, what harm would be done if he did leave these small leaks. Is there any real reason why the tunnel should be absolutely tight?

Mr. Clausen: I do not think myself that there is any real reason other than a sentimental one, inasmuch as when the water is let into the tunnel the pressure will be all the other way, and we have plenty of supply. It is not like New York City, where they do not want to have the water leak out of the tunnel on the way to the city. We have plenty of water in Lake Michigan. There is such a thing as spending more money plugging up these leaks than it is worth. The seepage water has a mineral in it, iron. There is no contamination from this water. The only place we must be particularly careful is going through the surface water in our shafts. There we sink steel shells and make it absolutely tight. But I think when we get through this tunnel will be tight, because the concrete is very dense. In fact, we notice when we drill in the side walls in order to put in a bar to hold the ventilating pipe, very frequently just as the drill goes through and hits the rock, a stream of water will come through that will shoot clear across the tunnel. That shows that the concrete must have been very dense.

George B. Springer, M. W. S. E.: Many things have been said by the former speaker which accord with my own thoughts on this subject. I may add, however, that I had the pleasure about two weeks ago of inspecting the Wilson Avenue tunnel at the invitation of Mr. Clausen, with several other engineers, and I can say from first hand information that the work is being carried on in a very efficient and I should judge a very economical manner. In these days when we hear so much said against the city government and political methods used, it is exceptionally creditable that the engineers of Chicago have undertaken this work.

The experience I have had in tunnel building has been altogether under the contract method on the tunnels of the Commonwealth Edison Company. These tunnels average from 300 to 500 feet in length, and are six feet, six inches in size. We have built twelve of them in the last thirteen years, an average of practically one a year, and all are under the branches of the Chicago River. About half of them are in clay and half in rock. The average cost of our tunnels has been approximately $30 a foot for the tunnels and about $60 to $70 a foot for the shafts. I believe that they are economically constructed, and we know that there could not be a

very great saving made in building them by day labor. There is one advantage the city has. They are able to utilize the machinery and plant used in these tunnels, because they are building them all the time. It might also be said that a corporation may choose its contractor with reference to his fitness for the work, whereas in a city government it may be more difficult to do this.

Chairman DeBerard: I would like to ask what you found the skin friction on the shaft shell in sinking these shells.

Mr. Clausen: The following is inserted as a matter of record from tests on sinking of a steel shell 11 ft. 5 in. inside diameter and 30 ft. high:

The total weight used to sink the shell was 163,646 lbs. With the weight of the timbers the entire load amounted to 92 tons.

To estimate the friction between the soil and the shell we have:

Load	184,000 lbs.
Shell	21,385
Brick lining	126,904
Total weight	312,289 lbs.

The total area of the shell in contact with the soil when it reached its final position was 970 sq. ft. Dividing the total weight by 970 gives approximately 322 lbs. friction per square foot of contact area. Comparing this figure with the friction indicated when the shell was sunk to elevation —4, we find that at that time the weight of the shell and its brick lining was about 116,000 lbs. and that the area of contact between the shell and the soil was approximately 240 sq. ft. This indicates that a friction of 480 lbs. per sq, ft. existed when the shell ceased to sink at —4. In this case the shell was forcing its way through sand, the area of contact with sand being 145 sq. ft. and with earth fill about 94 sq. ft. In its final position the shell was forcing its way through clay and was in contact with 405 sq. ft. of clay, 471 sq. ft. of sand, and 94 sq. ft. of earth fill. This indicates that the co-efficient of friction was reduced as the percentage of area of the shell in contact with the clay increased.

I should like to add one thing that I omitted to say in the paper, and that is that we are carrying all this work on on a strictly union basis, all union labor and union scale of wages, which is rather high when you consider the average wages paid in tunnel work in other parts of the country. I have just made a tabulation comparing the wages that we were paying last year and this year as against what was paid on the Southwest Land Tunnel, and I find the rates were last year 47 per cent higher than they were on that job and this year 58 per cent higher than they were on that job. The cheapest man working in a tunnel gets $4.40 a day. That is one of the muckers. The drillers and miners get $5.00 and then the skilled mechanics, such as electricians, hoisting engineers and so on, get $6.00, with all the prerogatives of overtime.

H. B. Kirkland, M. W. S. E.: As it is getting late I do not think that I had better take up much time to talk about my part of it. I might say, however, that we have furnished pneumatic mixers for railroad work, both to the railroads themselves and contractors, and also for municipal work, both to contractors and municipalities for use by the day labor system such as is the case with the City of Chicago, on this work for the City of Chicago the best record of progress has been made for any machine that we have yet had in operation.

I might also say something in regard to filling up the arch as one of the gentlemen here has stated that he had found that the arch was not filled up in all cases, on some of his work. The filling up of the key of the arch is a question merely of the efficiency of the men who are watching the concrete come out of the end of the pipe. Until they become accustomed to that work, they are sometimes timid about handling the pipe and they also sometimes think that the key will fill up entirely without any assistance as to the direction of the pipe, but if they watch the concrete coming out of the pipe and keep the pipe pointed accordingly, there should be no trouble from that source. The pipe is 8 in. in diameter, and leads over the top of the form to a point within 15 or 20 ft. of the back end. The concrete is filled up in the sides of the form until it commences to cover the arch at the rear. When this begins, it is necessary to watch where the concrete is filling up. For instance, if there is a low point in the rock roof where the concrete comes close to the form, the concrete may fill up there and leave a cavity beyond that point. This never occurs after the men learn how to direct the flow, as they can easily keep the low points clear by shooting around them or by poking loose any material that gathers there, before the concrete is filled up solidly at the rear. As far as I have seen it here on the Wilson Avenue Tunnel the key has been filled up solid to 18 in. and often more. Of course, when the concrete has set there will be the contraction of the concrete itself, leaving a small space between the concrete lining and the rock which in some tunnels might be objectionable and would require grouting. In this case the contraction of the concrete due to the setting would not leave a space large enough to be of any consequence. This is a solid rock tunnel and when filled with water the internal pressure will equal the external.

Chairman DeBerard: Mr. Kirkland, at the meeting of the American Concrete Institute here there was a paper prepared by Mr. Ridgeway, stating that in New York they found some difficulty in getting the proper mix for that type of mixer. Can you tell us something about the peculiar conditions they had?

Mr. Kirkland: The matter down in New York was handled by a different organization and I could not say, neither do I know how they handled it nor about the condition of the concrete. But *we* have never had any trouble securing a thoroughly mixed concrete except right at the beginning of the job when there is always

a little bit of difficulty in adjusting the amount of water and getting a gang organized. I have found that the best way to load a mixer is to fill the measuring hopper first with the proper proportion of stone and on top of it the proper proportion of sand, and on top of that place the cement, then, when the hopper is dumped, the sand drops into the voids of the stone, and the cement likewise. This arrangement is not, however, to obtain a good concrete mixture, but it prevents clods of cement sticking to the inside of the mixer. As far as the resulting mixture of the concrete is concerned I can say that we have tried all sorts of arrangements for charging the mixer and cannot see any resulting difference in the concrete. The important thing is to secure the right consistency by using the proper amount of water. If too much water is used in tunnel lining, the concrete will fill up at the back of the form and the water will run forward to the front end of the form and when the form is completed and moved, the concrete will show where the water has run down hill and left a streaked face. The correct amount of water to use is just sufficient to give the material an oily consistency so that it will flow, but so that there will not be any puddle of water running to the front end of the form. It is an error to suppose that it is necessary in shooting concrete through a pipe to have a large amount of water. Concrete can be blown through a pipe in any consistency, either with a large amount of water or with absolutely no water. The only thing necessary is to have a sufficient supply of compressed air stored up to carry each batch through. When this matter of adjusting the water is accomplished on a piece of work no better concrete can be secured, and as shown on the Wilson Avenue tunnel, the surface of the concrete is so smooth that the electric lights are reflected in it. The Wilson Avenue tunnel runs about 2 yds. of concrete per lineal foot. They have worked two shifts there with two 30 ft. forms and made 360 ft. per week. The concrete gang consists of about 13 men on each shift, and there is a small gang of 4 to 6 men who move the forms. This makes two shifts of 13 men and one shift of 4 to 6 men for each 60 ft. of tunnel lined.

Mr. Blanchard: In regard to the matter of the inspection of the concreting, I want to say that careful inspection of the work does not insure solid concrete when it is placed by this method. On the piece of work that I have been speaking of, the inspectors were first class, some of them having had previous experience on the Pennsylvania tunnels in New York, but, as I have stated, when the concrete was shot in behind the closed forms the bridging over took place rapidly and could not always be detected.

John T. Walbridge, ASSOC. W. S. E.: I am very glad, indeed, to have an opportunity to hear what a good tunnel these gentlemen are building, and how cheaply they are able to do the work. I think there are a lot of points the contractors can probably look into to their advantage, if these conditions are such as stated in the paper, which is no doubt the case. I was in the tunnel shortly after mining had commenced, and at that time it was being driven in first-

class shape. I think it was being cut out cleaner than any similar tunnel I have been in to date. I have not been in it since the lining has been started, but I intend to go out as soon as I can get the opportunity. The progress of 20 feet a day is something remarkable for this class of work and a great deal of credit should be given the men who have taken the trouble to do into the details of the problem and carry out the work in such a manner as to obtain this result. I attribute some of the rapid progress to the fact that the smoke has been removed from the tunnel quickly and fresh air replaced. Ventilating rapidly is something which has never been done heretofore in a very satisfactory manner in drifts of this length. I suppose the reason for this is that too small air pipes have been installed. An 18-inch pipe seems like a large pipe to put in, but it has evidently done the business. Just such points as this, also the proper care of track and close attention to small details, are what enable rapid progress to be made in this and similar work. It does not matter whether it be done by contract or by day labor. On work of this kind, as soon as it has been organized, and every one knows just what he has to do, the men work just as well for the city, I imagine, as they do for the contractor.

Another point which I suppose has helped the city in getting these results is that they have had plenty of money to spend, they have been able to experiment and buy all the plant they could possibly need on the job, and in that way they have been able ultimately to save large sums.

E. N. Layfield, M. W. S. E.: This question of contract methods versus day labor methods of doing construction work is, as you all know, a never-ending controversy. I believe that the contractor has a field, is entitled to his profit and that he is a necessary adjunct in the great bulk of construction work. This, of course, indicates that it is all the more to the credit of the men who have done this particular work so efficiently, as we know they have. The feeling that the profit that the contractor makes is so much loss, I think, is erroneous. The contractor gets his profit for services rendered, so that, when, under certain conditions, such as exist here, an engineering force of a city does work so efficiently and effectively, it is, as I say, very much more to their credit than it would otherwise be.

In the case of a corporation, such as a railroad company, which can select the contractors and say who shall bid on the work, there is a very great advantage over the case of a municipality where every contractor who thinks he can do the job and can get somebody to put up a bond for him, is willing to try it.

When an engineer conducts construction work by day labor he takes a very great responsibility upon himself. I had charge of some pretty extensive work some years ago by day labor, and I do not think I slept my normal number of hours at night until it was all done, and I wish to emphasize again that the fact that these gentlemen have been able to do this work under the difficult conditions that they had, is very greatly to their credit, and I am very glad to have heard how they did it.

THOUGHTS IN CONNECTION WITH THE ELECTRICAL SYSTEM OF SMALL CENTRAL STATIONS

By Albert J. Goedjen

THE DISTRIBUTION OF ELECTRIC ENERGY WITH PARTICULAR REFERENCE TO SMALL PROPERTIES

By A. Hardgrave

THE MANAGEMENT OF A PUBLIC UTILITY IN THE AVERAGE AMERICAN CITY

By Adam Gschwindt

THE CITY MANAGER

By Robert L. Fitzgerald

Four Papers Presented at a Joint Meeting of the Electrical Section W. S. E. and the Chicago Section, A. I. E. E.

April 24, 1916

Thoughts in Connection With the Electrical System of Small Central Stations

by

A. J. Goedjen.

The wonderful industrial progress of the electrical industry had its beginning about 1879, with the construction of the first four central stations in the cities of London, England, New York, N. Y., Cleveland, Ohio, and Appleton, Wisconsin. Its development in the last thirty-six years has demonstrated a vast amount of imagination and skill on the part of central station men and electrical manufacturers. National and sectional electrical associations, trade papers and technical schools have contributed largely by development, experiment and the diffusion of knowledge.

Before proceeding to the discussion of the relatively *small* central station, let us for the purpose of comparison, briefly review the remarkable achievements of its big brother,—the *large* central station. Because of the great industrial opportunities presented in

the *large* cities, the progress of central stations at these points has been far more rapid than in the smaller centers.

From an electrical standpoint, the great responsibility entailed by supplying numerous important consumers has resulted in the successful solution of the difficulties in long distance transmission, close voltage regulation and continuous service. In accomplishing this, it has, with the assistance of the manufacturer, developed and applied apparatus of remarkable capacity and insulation, has perfected various means of automatic voltage regulation, has standardized its operating methods, and has developed construction of remarkable efficiency and dependability.

In many cases it has provided duplicate machines and equipment, often providing duplicate lines to important points. Almost invariably it has provided facilities for working on lines and apparatus without interrupting consumers' service.

Its management has fearlessly assumed great responsibility toward its patrons, and its technical force has developed and is ever developing improvements with the constant ideal of making its service perfect—100% at the consumer's service, 100% of the time. It has been deservedly successful and consequently has been able to finance still further developments.

The *smaller* central station has been required to meet somewhat different conditions and in its progress has had a variable history. With the ever increasing popularity of electric service for street lighting, residence lighting and power, numerous small central stations were constructed in small towns throughout the country. In some cases these plants were municipally owned, although in most cases they were financed by private local capital. Unfortunately the men who founded these plants frequently had no conception of the business and employed managers who had no technical knowledge. Neither the owner nor the manager kept pace with the rapid improvement and increasing technique in the art, with the result that such small plants were often unsuccessful. These plants frequently changed management, sometimes from private to municipal ownership and vice versa, always with a change, but not necessarily an improvement, in ideas and methods.

On numerous occasions, the small plant did not progress because of the inability or timidity of the management to grasp opportunities. In other cases the small central station attempted to progress, but failed due to an improper handling of its problem. Having so little technical skill in any of its organizations, the small central station too often followed the advice of electrical material salesmen who were neither entirely competent nor entirely unbiased in their selection of methods and materials. Generally the salesman with the best business getting ways had the widest latitude in the application of his material. This lack of being able to discriminate, and the resultant dependence upon the salesman, has resulted in burdening the small central station with freak devices and infe-

rior materials which the more able engineer of the larger central station would not even seriously consider.

In numerous other cases good intentioned effort was wasted when the small station man thought of and used odd devices and schemes, not knowing that the same had many years before proved impractical. The result of this lack of information, failure to discriminate properly, and poor engineering, is reflected in the present considerable confusion of systems, materials and methods. According to a recently published electrical directory of the United States, there are no less than 4,700 central stations in towns of less than 50,000 inhabitants. An analysis of the data relative to

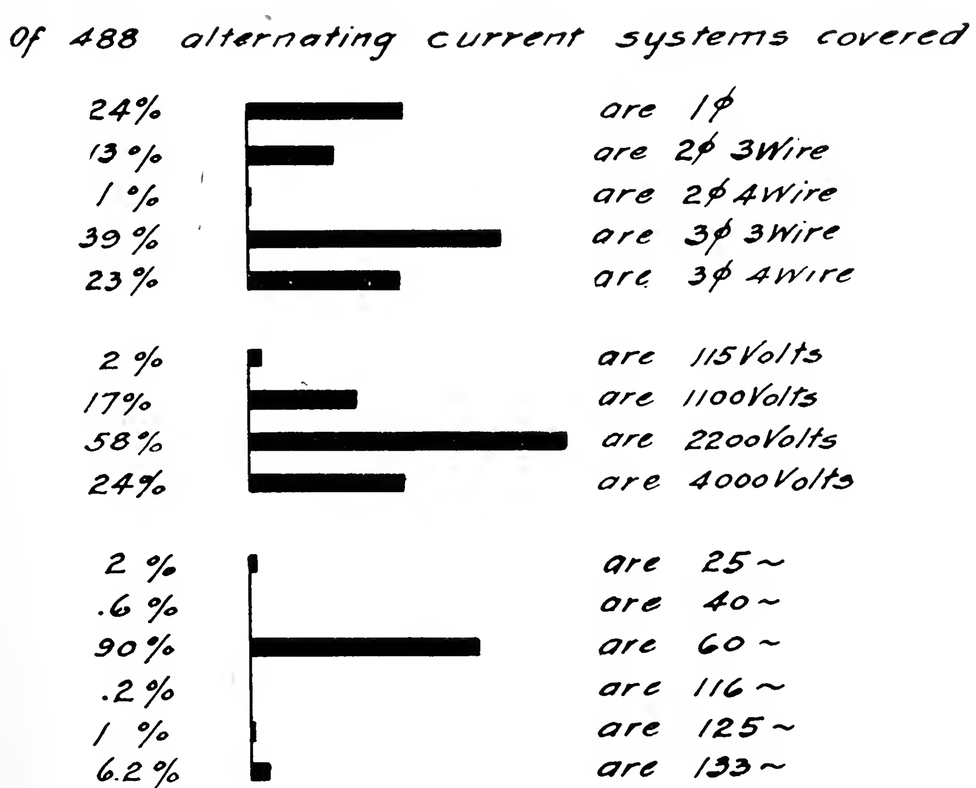


Diagram I

576 systems in six representative states indicates that 15% of these systems use direct current at voltages of 125, 250, 550 volts, two-wire and 125/250 volts, three-wire. How well some of these direct current systems are applied is not apparent, but it is evident that the voltage of direct current systems is *quite* well standardized. Of the total number of systems analyzed, 85% employ alternating current in *twenty-two* different combinations of number of phases, wires, cycles and volts, practically none of which are convertible into another combination without great difficulty and expense.

Diagram 1 illustrates the relative use of the various number of phases, wires, volts and cycles in the 488 alternating current systems analyzed. Please note in connection with the upper sec-

tion of this diagram the diversity of systems as to number of phases. Almost one-quarter of the total number of systems operate as single phase and about one-eighth operate as two phase. Three phase three-wire systems are most common with a very considerable, and I think ever increasing, number of three phase four-wire systems.

The second section of this diagram classifies these 488 systems according to voltage. It will be noticed that a small proportion operate at 115 volts, a considerable number operate at 1,100 volts, the greater part operate at 2,200 volts and about one-quarter of the entire number operate at 4,000 volts. In accord with the general tendencies to use higher voltages, it seems that 4,000 volts will become more generally used even in small stations.

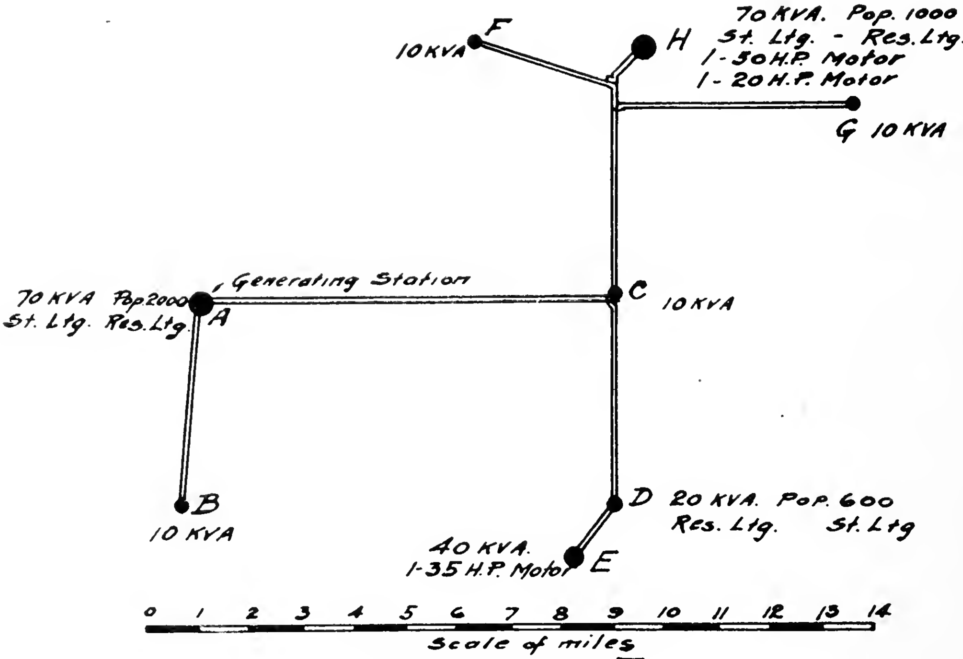


Diagram II

The third section of this diagram classifies these systems according to frequency. It indicates that sixty cycles is pre-eminently the frequency of the small system although several other frequencies are employed. Twenty-five and forty cycles are employed in several cases and 116, 125 and 133 cycles are still used in quite a number of small plants. It is very apparent from the preceding discussion that there is great diversity in the fundamental character of small systems.

As an example of the conditions which sometimes exist I will refer to one of the cases included in the previous analysis. This system has been developed in the last eight years and supplies lighting and power service to five small towns ranging from 450 to 2,000 inhabitants. It operates transmission lines over a total distance of 32 miles and serves a present peak load of 230 kv-a.

Diagram 2 shows the relative location of parts of this system and distances by referring to the scale. The relative magnitude of the peak loads at the various points is shown by the size of the circles. You will notice the generating plant is installed at point "A," a town having a population of 2,000 inhabitants and a peak load of 70 kv-a including power, street lighting and residence lighting. A peak load of 10 kv-a exists at point "B," point "C," point "F" and point "G." Point "H" represents a town of 1,000 population having a demand of 70 kv-a including one 50 H. P. motor, one twenty H. P. motor, street lighting and residence lighting. Point "D" is a town of 600 inhabitants with a demand of 20 kv-a consisting mainly of street lighting and residence lighting. Point "E" has a demand of 40 kv-a consisting mainly of one 35 H. P. motor. Various small motors are operated at all points.

Now I shall explain how this system was built. First of all its generation was made single phase, 60 cycle, 2,400 volts with two 100 kv-a and one 75 kv-a engine driven alternators. The local circuit in town "A" was supplied at 2,400 volts and all other points were supplied over a transmission line. The transmission voltage was 7,200 volts obtained by stepping up the generated voltage in a 3:1 ratio. The local primary distribution in "H" and "D" was made at 2,400 volts by means of 3:1 step down transformers, all other loads being supplied directly through 7,200 volt transformers. The large single phase motors were purchased and installed by the electric company in each case.

Needless to say, this unfortunate single phase solution of a transmission and motor problem resulted in very poor regulation, did not allow for increased load and required a large investment in apparatus which was not suited for the conditions and can only be disposed of at great loss. This system became so involved that in order to avoid impending obstacles, it was decided to shut down its own generating plant and purchase service from a central station in a city thirteen miles away. I have referred to the difficulties which resulted from poor engineering in this instance and would not go farther with this case but for the fact that its solution is rather interesting. The central station selling the energy is operating a 4,150 volt 3 phase four-wire 60-cycle system and has a four-wire overhead power feeder extending three miles toward the rural system to a point from which a higher voltage line could readily be extended. This condition is indicated by diagram 3.

In order to make use of the 7,200 volt transformers of the rural system the 4,150 volt four-wire system was stepped up in a ratio of 3:1 to 12,450 volts with 7,200 volts to the grounded neutral wire. Fortunately it happened that the system could be divided into three almost equivalent branches at the point "C" and this was done by temporarily connecting one phase and the common neutral to each branch circuit. In order to obtain accurate voltage regulation a single phase 2,400 volt induction feeder regulator was installed in each phase and adjusted to maintain constant voltage at

the points "A", "E" and "H". This scheme has worked out very successfully so far and has greatly improved the service. Ultimately it will be necessary to make the entire rural transmission four-wire but just at present the rural company is sufficiently relieved in that its immediate problems are solved. I have digressed and described the way in which this case was handled, because it brings out an unusual application of the feeder regulator.

In the foregoing I have referred to the diversity which exists in the classification of *systems*. There is every reason to believe that the diversity is even greater in the matter of materials and design of the distribution system. Watt-hour meters, lightning arresters, transformers, oil switches, switchboards, anchors, crossarms, and line hardware are all found in considerable variety, some good and some bad. In station layout and primary lines there is too

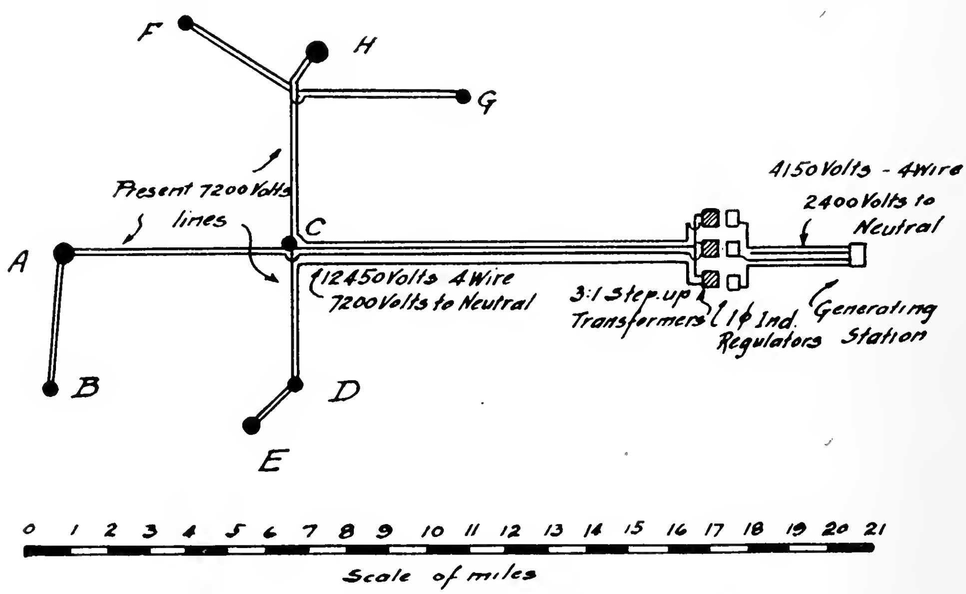


Diagram III

common a practice of extending only one feeder from the station not allowing any means of double feed in case of emergency. In distribution work, transformers invariably feed too large a section resulting in excessive secondary drop and poor regulation. There are many other features which might be referred to, but I believe are too well known to require enumeration.

It is generally realized that most small central stations have fallen behind and find it difficult or almost impossible to master the manifold new branches of the business and to cope with the problems which present themselves. It is gratifying to know that state electrical societies realize this fact and are working diligently and accomplishing much good through cooperation, interchange of views and other methods. It is understood that one such State association is assisting the small company very materially by help-

ing it to temporarily employ expert and experienced assistance in the solution of its most difficult problems. In this way, high class engineering knowledge embodying the most approved central station practice is placed at the disposal of the smaller plants, giving them a service which they would have great difficulty in obtaining in any other way.

The fact that your able body has set aside an evening for the consideration of the small central station, indicates that it realizes the present condition of many small stations and the great good to be accomplished by lending a helping hand. This is without question one of the most vital subjects relating to the central station branch of the electrical industry, and anything which this body can do in hastening the day of better understanding, better methods, and approved standards, will reflect for the betterment of this—one of the world's greatest industries.

The Distribution of Electric Energy With Particular Reference to Small Properties

BY

A. Hardgrave.

Those of us who may stop momentarily to look back over a period of a few short years, observe with surprise and satisfaction, the wonderful progress which has been made in the development of the Central Station industry.

Starting with the first Edison station which was installed in Appleton, Wisconsin, in 1882, the equipment of which consisted of small, high speed, belt driven D. C. generators, the early development was confined almost wholly to the generation of electricity for illuminating purposes.

During the following years, the generating and distributing equipment was greatly improved to keep pace with the rapid increase in the use of electric energy for lighting purposes. But that class of service, at its best, required the operation of the plant during only a few hours of each day; and, therefore, the period during which a revenue could be earned on the investment involved was confined to a few early evening hours.

The next step in the development of the industry came with the use of electric energy for operating small factories and for other power purposes during the daytime. The energy used for these purposes was supplied from the same generators that were used to give lighting service during the early hours of the evening. This resulted in the use of the investment in the Central Station a greater number of hours each day, and the amount of energy sent out from the station was thereby increased without increasing the interest or overhead costs. Because of the heavy expense involved in transmitting D. C. energy to distant points the territory to be

served was confined to a small area in close proximity to the generating station.

With the development of the alternating current system, many of the earlier difficulties in generating and transmitting electric energy were overcome. Under this new system, the Central Station was able, with lower copper investment, to reach out with its distributing lines and to serve customers at all advantageous points within the city. This resulted in a rapid increase in the use of electric energy for both power and lighting purposes, and this increased use, in turn, greatly improved the load factor on the system—particularly when contrasted with that derived during the early days from a purely lighting business, and enabled the Central Station to largely increase its revenue by the increased use of its investment in generating and distributing equipment. Likewise, the securing of various classes of power and lighting loads, with their greatest individual demands occurring at different times during the day, gave to the system a high diversity factor, which resulted in a smaller maximum demand on the generating equipment than the combined demands carried on the distributing system. In other words, the greater the diversified demands on the station, the greater the amount of business that can be carried per kw. of station capacity; consequently, a reduction in the station investment per kw. of load connected. It will readily be seen that economical generation and distribution of electric energy depend greatly upon the load and diversity factors developed. The greater the development of these factors, the lower the production costs at the switchboard and the fixed charges per kilowatt-hour.

The development of the Central Station industry and the value of the diversity and load factors in the manufacture of electric energy has been thoroughly discussed many times by eminent authorities. I have, however, dwelt upon this subject briefly in order to bring home to you the two most important factors entering into the economical distribution of electric energy, namely—the load factor and the diversity factor.

What has been said refers, generally, to properties in large cities where are usually found a large number of industries and other users of power. These industries, with greatly diversified demands, have made possible the rapid development of Central Stations in such cities. These natural advantages, however, are not usually found in the smaller cities. This is especially so in communities of less than 5,000 people; and it is towns of this and smaller size which I wish to discuss.

According to the United States Census of 1910, there are in this country, 12,956 incorporated towns with less than 5,000 population, each; and with a combined population of 12,224,000 or 13.3% of the total population of the United States. Of these communities 11,784 with a combined population of 8,118,825 or 8.8% of the total population of the United States, have less than 2,500 inhabitants each. A great number of these towns are supplied from

isolated plants, and with night service only, while many are not enjoying the benefits of electric service. In order to profitably serve these small communities, there must necessarily be designed and installed a system of transmission and distribution lines at a cost in proportion to the revenue which can be secured. The ratio of investment to the annual gross revenue must decrease in direct proportion to the size of the community.

The growth of the Central Station industry has been so rapid that the entire time, energy and resources of managers, operators, engineers and investors have been devoted to the development of public utilities in larger cities, with the result that the development of electrical properties in small communities has been neglected by them, and left to the local men, who have had neither experience nor capital with which to work.

Laboring under such handicaps, the service furnished was usually poor and unreliable, and, in most cases, the plants served lighting customers only and were not operated during the day. These conditions retarded the growth of the electrical industry in such towns. No doubt, there was just cause for such a condition since the pioneer development would naturally occur at points offering the best advantages such as found in large industrial centers, containing numerous big power users with diversified demands and higher load factors, and where it was possible to obtain maximum generating efficiency through the use of large generating units.

The development of efficient electrical transmission systems provided economical methods of building up and developing the small municipalities which had previously been considered unworthy of our time and energy, and not a few of the leading men of our industry were quick to realize the value of grouping and connecting together with transmission lines a number of such towns since they could then be served from one or two large, economical generating stations, located at the most advantageous points on the system.

The commercial transmission and distribution of electrical energy in small properties present many problems more complex than are found in properties located in larger cities. The word "commercial" has been used in this instance to clearly define the difference between the use, on the one hand, of high construction and operating standards, which may be termed "high-class engineering," carrying high initial investment costs and annual fixed charges; and, on the other hand, systems constructed and designed at a moderate cost, commensurate with the development possible in the smaller towns. This, in many cases, is the difference between profitable and losing ventures in this class of properties.

A few of the problems met in the operation of small properties, especially those which I particularly wish to discuss, are:

Inexperienced management.
Low density of population.
Low diversity and load factors.

Low income per customer.
Unprofitable service.

The necessity of keeping the investment in transmission and distribution systems to the minimum.

These problems are evident in most towns under 5,000 population; in a large number from 5,000 to 10,000 population; and in a few with popluations in excess of 25,000.

The owners and managers of small electric properties, no doubt, have applied their greatest endeavors toward the development of the business. They have, however, been seriously handicapped by the lack of funds and the training necessary to the development of the industry. These conditions have necessitated piecemeal financing of additions and extensions to plant and equipment resulting in inefficient and unprofitable systems. Properties of this size and class cannot afford to employ the services of men who are fully qualified to finance, build and develop public utilities.

As to *low density of population:* In towns of this size real estate is inexpensive and the residence portion of the town is usually scattered over a considerable area, since there is no necessity for the congested condition prevailing in large cities, and it is not uncommon to find from 5 to 10 residences in a block, whereas in the larger cities, a block usually contains 20 to 50 or more residences. It will readily be seen, therefore, that, under conditions such as these, a greater amount of distributing lines per customer is required than in large cities. This increases the initial investment and the annual cost of service per customer. Larger Central Station Companies find that it costs very little more to serve 50 customers per block than to serve five. It is, therefore, apparent that in the small property, this low density condition is a serious problem.

As the principal business of electric plants in small towns consists of lighting service, which is rendered for only a short period each day, the load factor on the system is quite low. Because of the early retiring habits of the people, and, in many communities, the turning off of the street lights at midnight, the evening load on the station is further reduced. Very little diversity is secured under such conditions.

In the small towns throughout the country, especially where the large percent of the population is wage earners, the wealth or earning power of the inhabitants is low, and therofore, the amount expended annually for electric service is much less than in large cities. This refers especially to earnings per capita from commercial, residence and street lighting service.

In a great number of small towns it is necessary to operate the plant 24 hours per day in order to fulfill franchise obligations. In some towns, where good day loads can be developed, such service is not unprofitable; but, in most cases, those plants having very light loads are operated at a loss for 20 hours each day, thereby

exhausting the profits secured during the other four hours of the day. Very frequently, small plants which are operated at a small profit, when giving only night service, operate at a loss when forced to operate 24 hours per day.

It is quite apparent, from the foregoing, that it is necessary to keep the investment in transmission and distribution lines down to the minimum.

The average small town, ranging from 500 to 2,500 population, does not offer the opportunities for development existing in larger cities, and consequently the revenue received per capita or per customer is much less. It is, therefore, necessary to limit the investment in such towns in proportion to the revenue received, taking into consideration, in each case, the cost of production and distribution. It is purely a question of economics and due consideration should be given to the fact that, as a rule, such communities do not enjoy the rapid increase in population which is constantly going on in larger cities and industrial centers. In fact, many such communities have not increased in population during the last decade. Therefore, great care should be exercised when designing and laying out transmission and distribution systems for this class of towns to keep in mind the fact that, in most cases, the development along the lines is limited to existing business, and not upon the town's future growth. It is usually necessary and profitable in large cities to construct transmission and distribution lines, not only for the present requirements, but with sufficient capacity to provide for future growth. In such cases, a very high point of saturation can usually be obtained. This is, however, not true in small properties, and therefore, systems must be installed at moderate cost if profits are expected for the investors.

In order to bring out more clearly what I have in mind, I will refer to a property consisting of five small communities, interconnected with a 22½ mile, 13,200 volt transmission line constructed with No. 6 B. B. galvanized iron wire, strung on 25 foot and 30 foot cedar poles, spaced forty to the mile. One half the line is single phase and the balance three phase. The power station, which consists of high speed, non-condensing units and return tubular boilers, is situated in the largest town of the group with a population of 3,500.

The other four towns, lying within five to ten miles of the central station are small villages, having from 400 to 700 population. The total investment in the system amounts to approximately $16.50 per capita. The gross and net earnings per capita for the year, 1915, amounted to $5.40 and $2.27 respectively, notwithstanding the fact that one of the small towns was receiving dusk to midnight service only. The operating ratio for the year was 58.2%, while the net earnings amounted to 12.57% on the investment.

The total investment apportionable to the four small towns, including the 40 kw. station capacity and 12% supervision and engineering charges, amounts to $11.31 per capita, as against $16.50 per capita for the entire group.

The gross earnings for three of these towns for the year amounted to $7,044. or $4 per capita. The total operating expenses and taxes, including energy at 2.85c per kw.-hour amounted to $1,896. The net earnings for the year amounted to $5,148, which is equivalent to a return of 20.5% on the investment. The net earnings from these towns amounted to about 40% of the total net for the entire system.

The value of the four small villages to the initial property can be fully realized when it is understood that no additional operating force or additional station capacity has been required. In this specific instance, the three phase transmission line cost approximately $450 per mile, while the single phase line cost, exclusive of the right-of-way, $386 per mile.

Notwithstanding any criticism which might be made concerning the use of this class of construction, the actual losses on the system are under 20%. One of the most important factors to consider is the profitable showing on the balance sheet.

Other similar groups of properties, with which I am familiar, are today laboring under extremely heavy fixed charges due to large initial investment in highclass transmission and distribution systems—a class of construction which is entirely unjustified in such communities. In such towns, using high class, expensive methods, the total transmission losses have not decreased, the maintenance is no lower, and the continuity of service is no better than that of the small iron wire transmission system heretofore referred to.

There are today hundreds of towns ranging in population from 300 to 2,500, lying within commercial transmission distance of existing stations and transmission lines that are entitled to, and should enjoy the advantages of 24 hour unlimited supply of electrical energy. Obviously, if such small towns are to enjoy such advantages, it is essential to provide transmission and distribution lines and equipment at much lower cost than has previously been done: and no doubt, when the value of such communities to existing systems are fully realized, our manufacturers and engineers will be quick to design and provide lower cost equipment and material, and thereby make possible the development of these small towns.

The grouping together and serving of a large number of small properties from one central station gives to the entire system some of the most important advantages secured by the central station in the larger city—viz: concentration of management, production and distribution economies, and especially, the important advantage of "high diversity" and "load factors." These factors are particularly noticeable, where it is possible to secure in one system a number of towns, each having different characteristics, and containing people with entirely different habits and customs, such as

mining, industrial or purely residential towns, with peaks occurring at different times of the day.

The grouping of small properties in this manner diversifies the financial risk of the business and, in turn, gives greater stability to the entire financial structure, and makes the securities of such companies more attractive to the investor. It will readily be seen, therefore, that concentration of management, in both production and distribution, are (considering the present development of generating and distributing apparatus) the essential economic factors that make for successful and profitable operation of small properties.

The Management of a Public Utility in the Average American City.

BY

Adam Gschwindt.

In attempting to theosophize and analyze a subject of this title it should not be construed that my talk will be a specific to cure all ills or remedy every situation. Rather my remarks should be taken in a suggestive sense—something that will start a train of thought that will ultimately prove of value.

It is generally conceded among writers and public speakers that only one line—one phrase—one thought reaches one reader or hearer during a long discourse—but different phrases and thoughts to different hearers. The side-splitting story may produce a gale of laughter from one and only the smile of courtesy from another. So that sometimes it so happens that the poorest speech puts forth a phrase that lingers in someone's mind with resultant generation of ideas.

But to the subject—the first consideration, of course, must be the man. What are the requisites of a manager or executive? An executive may be a man who runs any business employing men successfully and with satisfaction. Then the qualities of an executive should be something like the following: Solidity, judgment, diplomacy, courtesy, even temper, discernment, foresight, mental bravery and manly dignity.

When these qualities are combined we have a "commander of men." I have purposely left out of the above list a "thorough knowledge of the business." To my mind the latter is of secondary importance although important in itself. Knowledge of the business may be acquired in a short time, but the first named are inherited or drilled in from infancy.

The late owner and editor of the Kansas City Star, one of the greatest successes in newspaperdom, started the paper when forty years old and without previous experience. But he was a man first and it did not take long to acquire the technic. The student of

the human family is the successful manager, no matter what his previous education.

It must not be construed that it is my intention to convey the impression that an ignoramus can jump in and run a central station,—not at all. But if one has the qualities of an executive the technical side will soon develop, at least sufficiently for the purpose.

His work—

First of all the manager must set the example for his people to work by. In promptness, in diligence, in thoroughness, in demeanor he must act and do as he would have those subordinate to him. The privilege of reprimand should be exercised carefully and when necessary firmly and without temper. A reasoning heart to heart talk with the delinquent will do more than a tirade. And if it is thought necessary to use severe expression, dismissal would be a better plan to follow.

Your organization should be planned carefully for harmony, because harmony in the organization begets results. It is true that some companies are successful that are out of tune, but this only proves the rule and perhaps that same organization would be twice as profitable if each member was in accord with the other. From a harmonious organization you can get service and it is needless for me to point out how important an item this is in the welfare and success of your company. A perfect service should be the slogan of every central station. It should be advertised, advocated and spread broadcast that no expense is spared to give a perfect service, and a large part of the manager's time should be given to seeing that a perfect service in its smallest details are given the patrons.

Quick, prompt, efficient service will cure many sore spots that might grow to an incurable malady. The plant service must be perfect. With generating stations as they are today there should be no excuse for lack of service. The chief should have foresight aided by the manager to anticipate all contingencies.

There are no accidents except those by action of the elements —the rest are due to carelessness and lack of foresight.

There is one point that may be brought out here, and that is that we should not carry efficiency to the point that will jeopardize service. Take a chance? Yes, but not to the point of foolishness. Do not lose prestige with your patrons by trying to save the last cent in operation. This would be penny wise and pound foolish. True, you can excuse it once, perhaps twice, and possibly a third time by suave explanation but your patrons lose confidence and it is costly to get it back.

Economical operation should be carried to its highest development but the point is reached just before jeopardizing a "perfect service."

And now for just a few words about the utility and the public. It must be remembered that the utility is one of the big corporations

of the city with more customers than any one merchant, and is looked up to and discussed freely on account of its quasi-public character. The mere fact that it is permitted to do business on sufferance of the people through franchise puts the utility on a different basis from that of the merchant and manufacturer. And yet a perfect service will do much to make the utility the same as the merchant.

You have no doubt been puzzled at times, as I have been, at the attitude of certain individuals towards your company,—good friends but with a certain reserve when speaking of your company. Just what can this be? Is it the feeling that a utility is piratical? Was there a reputation established years ago that we must live down? It would seem that this is the plausible explanation.

Therefore, the obvious course is to quietly and with dignity counteract this feeling not so much by words and argument as by conduct and actions. Conduct our business justly and squarely, with unfailing courtesy, and with a dignity that commands respect. We should enter into the active civic life of the community not because we have to but because we want to. Be careful that in taking care of the influential men of the town we do not forget the mass of patrons. Pay as much attention if not more, to the plant of the workman customer than to the rich man. The workman may have more time to talk of his neglect and is much more apt to feel a slight than your bigger man. Your organization must be drilled in courtesy and fairness to every one, high or low.

A successful manager is one who knows what details to drop, who has confidence in his assistants and who knows how much responsibility to put on his subordinates.

To keep pace with growth one must necessarily be relieved of certain minor details that have been a part of the regular routine and the same applies to the head of the department. As the number of consumers and output increase twice, three and four times it must be apparent that additional help is needed in management. The only way relief may be found is to delegate certain duties to subordinates. There may be a protest from the patrons at first, but a firm stand must be taken and proper authority delegated. Let your subordinates' names be used freely in the conduct of the business.

The greatest manager of modern times, Carnegie, was at all times ready to give credit to those under him. Marshall Field's success was due to confidence in subordinates and getting the best out of them. Taken all the way through, the great successes were managers of men rather than able artisans.

Give credit freely and watch carefully the result, prod occasionally (indirectly if possible) but above all encourage, energize and keep your organization at a high pitch of enthusiasm, working with, not against, each other, because it pays and pays well, not only for the present but for the future.

May, 1916

The City Manager.

BY

Robert L. Fitzgerald.

Before starting on the subject of this paper a few remarks on the prevailing form of municipal government are probably in order.

The form of municipal government prevailing throughout the United States today is a copy of our national form of government with some slight modifications. This form of government was laid out by the framers of our national constitution and is probably as good as any that could have been designed at that time. After its adoption by the national government it was adopted by the several states and again adopted by the cities, towns and villages. It may still be considered adequate for the state and national governments (although this is a debatable question) but it is quite generally conceded by students of political economy that it is no longer an efficient government for the smaller municipal units of our political system.

The numerous shortcomings of this form of government have made themselves apparent in countless instances with which we are all more or less familiar. These shortcomings have created political unrest in the municipalities throughout the country, that is apparent from the large number of municipalities that have either changed their charter or attempted to change it within the past ten or fifteen years. Up until very recently these changes have resulted in some form or other of the so-called commission form of government. In more recent years the change has been through the commission form to, or directly to what is known as the commission manager form of city government. Galveston, Texas, was the first city to adopt the commission form of government and the change was made immediately after the big storm of 1900 had practically wiped the city from the face of the earth. Dayton, Ohio, adopted the commission manager form after the big flood of 1913 had wrought havoc throughout that section of Ohio. The efficient manner in which the emergency commissions brought order out of chaos in these two catastrophes probably gained the confidence of the people in the new form of government. Under such conditions as existed in these two cities the best business men of the community found time to exert their best efforts for the good of the city with the results that would naturally be expected.

The city of Staunton, Virginia, was probably the first to try out the city manager plan. There was no change in the city charter at that time, the office being created by an act of the council, and the duties and authority of the manager were defined to a certain extent by the council. The plan has met with more or less success but it can hardly be expected to meet with continued success until such time as the manager is given full authority over the municipal

organization, and is free from the influences of individual councilmen. Springfield, Ohio, was probably the first city of importance to adopt the commission manager form of government in its more advanced form. The city charter was changed so as to replace the former city council with a commission elected at large. The new charter provided for the selection of a city manager by the commission and clearly defined the duties and powers of the manager. Dayton was the next large city to adopt this more advanced form of city government and the marked degree of success obtained in these two cities has been published throughout the country in numerous magazine articles.

The success of the new form of government has aroused interest throughout the country, with the result that there are now eighty-two cities in different parts of the United States, including cities, villages and towns of all sizes that are operating under some form or other of the city manager form of city government.

The results obtained from the new system, from all of the cities that have adopted it, are not available at this time because the system has not been operating in many instances long enough to have had a fair trial. However, the results obtained in the few cities where it has been in use a sufficient length of time brand the system as a decided advance in municipal government and indicate that the turning point in city politics is about at hand.

Those of you who have followed the public service business during the past fifteen years can remember the wonderful improvement in the business from the standpoint of service, operation and earning capacity that occurred as the various properties throughout the country passed under the control of the large operating syndicates and the management passed from the hands of the old school public service managers to the hands of the highly trained scientific manager that guides the destinies of the industry today.

The condition of operating efficiency that existed in the public service plants of fifteen years ago might be considered the height of perfection when compared with the state of operating efficiency obtained in the average American city today. If the new form of government is permitted its full development, according to the ideas of its framers, the results in the form of improved and extended service at greatly reduced rates will outdistance the most shining example of the results of the introduction of progressive and scientific management into the public service industry that is on record today.

With the widespread adoption of this new form of city government comes the introduction of a new profession, that of city management, and with it a demand for city managers. As this profession is still in its infancy at this time, it cannot be definitely determined from what field of business the men best adapted for the work shall be chosen. However, a careful analysis of the duties of a city manager will show that the duties resemble in a general way the duties of the manager of a public service corporation.

The successful city manager must be an able executive, he must be able to deal with the public with the least possible friction, he must have some knowledge of accounting and cost keeping methods, he must have some knowledge of engineering, he must have the ability to develop a keen sense of interest in the general welfare of the community which he manages, and above all he must be absolutely honest. The extent to which all these qualifications are necessary depends upon the size of the city to be managed, upon which depends the ability to hire highly trained experts as heads for the several departments, but executive ability and absolute honesty are essential for cities of any size.

As a knowledge of engineering is probably the most difficult of the necessary qualifications for an untrained man to acquire, and because the majority of our municipalities are not large enough to maintain specialists in each department, the engineering profession will probably be called upon to supply the necessary men to fill the positions of city manager. This conclusion is substantiated by the fact that fourteen of the sixteen city managers that attended the second annual convention in Dayton last November were engineers by profession.

The choosing of the manager is probably the most important problem that confronts the city commission. Upon the ability of the manager depends the success of the entire system, as does the success of any business depend entirely upon the management. Frequent changes of managers are detrimental to the system because they destroy the continuity of fixed policy and create openings for the spoils system. For this reason the selection of the first manager is all-important.

As the profession is still in its infancy and might be considered in what is usually termed the experimental stage, the number of eligible candidates for the position is quite limited. There are numerous advertisements in the current trade journals advertising for positions as city manager, but these advertisements are mostly from men who can hardly be expected to make the system a marked success, because the man who has the ability to make it most successful is probably pretty well located and cannot be induced to change to a position that is more or less experimental and may be somewhat subject to the whims and fancies of the voting populace unless he is going to be benefited by a substantial increase in salary. Until the new system has passed through the experimental stage and the new profession has been permanently established capable men for the position of city manager will demand comparatively large salaries.

When a man is confronted with the problem of deciding between remaining in his present position and accepting an offer of a position as city manager a few of the questions that he gives careful consideration are:

To what extent is the position a permanent one?

How long will it take to educate the voting public to the point where they will keep properly informed on the results being obtained by their city government and lend their active support to the system that will accomplish the object of city government at the smallest expense?

Does the present administration honestly desire to install a city manager that will place the city on an efficient operating basis regardless of how many of the friends of their political constituents will lose their pensions by the change?

Will a conscientious effort to enforce the laws without discrimination and manage the affairs of the city in a business like manner be appreciated and justly rewarded?

Any one attending the city managers' convention in Dayton last November could not help noticing how the very young men predominated in number among the managers in attendance. The fact can probably be accounted for on the theory that older men of more experience and possessing the desired qualifications could not be obtained for salaries that the respective cities thought they could afford to pay. The result was that the commissions selecting the managers have turned to the younger men whose short records indicate possibilities. The young man whose entire life is before him, and whose future depends entirely upon the degree of success obtained, certainly has every incentive possible to exert his best efforts to make a success of the system. After accepting the position and taking office the manager will find himself face to face with the problem of reorganizing, which in most cases will mean a complete house cleaning from cellar to garret, because it is a hard matter to teach an old dog new tricks. After reorganization the installation of system begins and it will usually be found necessary to install a complete new and adequate accounting system and a new system of records. After the system is installed and running smoothly the real work begins. The operating methods of the various departments must be studied and means devised to stop the waste and leaks. After these problems are worked out and the operation appears to be on the best basis obtainable the manager feels that he is beginning to get things into such a condition that he can spend a little time to partake of some of the few amusements that life affords. About that time he realizes that the city is growing rapidly and the public demanding more and more in the way of service from the municipal government. He finds that he is confronted with a few such problems as:

Garbage and waste disposal plants, sewage disposal plants, water filtration plants, booster mains for the water distribution system, adequate water supply and storage, new fire stations, railroad grade separation, new municipal building, elimination of dangerous street intersections, ornamental lighting installation, parks and playgrounds for the children, installation of police and fire

alarm systems, and numerous other problems that are forever coming up in a modern and growing city.

The profession holds forth wonderful opportunities for the man with unlimited dynamic energy, untiring love for work, the moral strength to follow his own convictions, and the necessary nerve to pioneer in the unexplored field.

Before closing I might make a few remarks in regard to the status of the city manager in the state of Illinois. There are at present only two municipalities in the state under the manager form of government, Winnetka and Glencoe, both of which are north shore suburbs of Chicago, and adjoining each other. These villages made no change in their charters at the time the managers were installed but are still being operated under the original charters granted about 1860. The position was created by a resolution of the council. In my own case no attempt was made to define my position. I was given a salary, a title and told to find my place. I spent six months in finding it.

The first fiscal year under the new form, just closed on March 31, and the auditor's report, will show a decrease in the deficit of the general cash account from four thousand to about two thousand dollars, the conversion of a four thousand dollar deficit in the water department into a cash surplus of six thousand, and an increase in the net earnings of the municipal electric light plant of twenty thousand dollars for the year.

DISCUSSION

James N. Hatch, M.W.S.E.: There is one thing that I think might be said in the way of a general discussion which is especially applicable to small stations or stations for small villages. It is true, as Mr. Gschwindt has told you, that these small stations will soon cease to exist, but this has not yet been realized, so they must be reckoned with for a while yet. The one great danger in designing a station for a small community is the danger of spending more money in getting your plant installed and going than you can ever justify, or, in other words, in getting so much spent in it that you can never bring rates down to what they should be. There are two or three things in the design of a small station which are often grossly miscalculated, and which can never be properly remedied. One that I have noticed particularly is in regard to coal handling equipment. In a small station the coal is generally unloaded and fired by hand, and this old-fashioned method seems to hurt the feelings of the financial people, especially where they have been around some of the large stations where it is handled by machinery.

I have in mind a case of a small plant that was generating about 300 kilowatts on the maximum load and was practically shut down at night. The principal owner of this plant was very much worried over the way the coal was handled. This was a plant which ran an electric railway. They hauled the coal on the electric rail-

way from the steam road about a mile down to the station, unloaded it by hand and fired it by hand. The owners felt that good money was being wasted and were very anxious to get a coal handling plant installed. I said to them to begin with, when I looked it over, that I did not think there would be any coal handling appliance that they could put in that would be as economical as the one they were using; but they wanted a report on it and I made them a report. It would have been necessary to bring a side track in from the steam road, which was about a half a mile away and bring the coal cars up on a trestle so that they could be dumped into a pocket. In this way the coal could have been delivered directly into the station in front of the boilers. I found they were using about half a carload of coal per day and the improvement would cost about $30,000. They could not have saved any men in the power station, and the cost of delivering the coal to the station from the steam road would have been about doubled.

There are a great many things of this nature that are put into small stations and made a drag on the station that can never be justified.

On the other hand, in small stations where condensing water is required, an inexperienced designer is apt to be too economical about putting in condensing water equipment. In some of these small stations water will be lifted two or three times before it gets to where it is wanted, and that loss goes on forever. This could often readily be overcome or cut down perhaps half by a little good engineering, providing a gravity method of bringing the condensing water to the plant.

Such things as these it seems to me are the ones we have to look into most carefully and such things all have to be designed before the station is designed. These all have to be figured out on paper and studied out and balanced one against the other and brought into the design of the station as a whole before any part of the station is built. A great many stations are designed, and built, before the coal handling problem is solved, or the condensing water problem is understood. In fact, some of the vital elements of an efficient power station seem to be forgotten until it is too late to remedy the matter.

Of course, that could be elaborated on and carried through the transmission layout and all through the whole system,—the great danger is of getting so large a capitalization that it can never be justified.

A. C. King: There is one point which has been touched but not dwelt on particularly, which is one of the most important factors in a small central station. Mr. Goedjen brought out the fact that the losses in the distribution system, electrical losses, are ordinarily, or can be, at least, kept down so as to be commensurate with those in a large system. On the other hand, the losses in generating, particularly in the steam end of the station, are enormous compared

with our larger stations. I have in mind some small stations whose maximum load runs from 125 to 250 kilowatts where the monthly coal used per kilowatt hour runs from about nine to ten pounds and the amount of water evaporated per kilowatt hour has been equal to fifty or fifty-five pounds. Compared with our large modern stations these figures are very high, and when we take into consideration the fact that there are a great many of these small stations, it is readily seen that this is a very important factor. In many cases these inefficient conditions are brought about by improper selection of the size of the units. If a man wants to build a plant in a town he goes to the nearest town where he can find a second hand unit that will nearly fit his requirements or that he thinks will, and he buys that because it does not cost so much in the first place and his freight charges are low. He ships it to his home location and installs it and then the coal bills begin to run up.

Some years ago a great many people thought the solution for the cheap generation of power in small stations would be brought about by internal combustion engines, using first gasoline, then kerosene, crude oil, and finally producer gas. All of these proved successful to a certain degree, but when reliability and flexibility were properly considered these forms of generating units were not nearly as desirable as steam. The European practice has brought us now the locomobile type of steam unit, which has been so far but little used in this country. It possesses extremely high efficiency, but its flexibility and some of its other qualities are not particularly desirable. On the whole, the steam unit seems to be a little more than holding its own for the small station.

The final analysis of the central station problem, it seems to me, is to do away with the small central station as much as possible and to connect the small plants together in one large or medium sized system. This is a long step in the way of conservation of our natural resources.

Peter Junkersfeld, M.W.S.E.: I think we are all to be congratulated on having this very interesting group of papers. The first two papers, particularly, lend themselves to the illustration of an old saying, that you must always cut your coat according to the cloth. In a great many of these small communities that we are talking of this evening the cloth is very short. There is not much of it. Therefore the coat must be small. In addition to that, these small communities do not require and do not want and do not need a very large cutaway coat tailored in the latest fashion.

In the development of electrical enterprises all over the country there has probably not been sufficient discrimination. People did not realize the vast difference between the cloth and justifiable need of a large growing community and the cloth and justifiable need in small communities, many of which, as one of the speakers pointed out, have not increased in population in a decade or more.

Right here in Chicago we have had some instances. Some

eighteen years ago, there were seven different plants and systems south of Thirty-ninth street. They sprang up during or about the time of the large annexation to Chicago, and were in separate suburban or neighborhood communities. A good many of these companies started out to supply only one little community, but they became overambitious and some of them lapped over into other communities, or neighborhoods, and pretty soon there was very fierce competition with a great deal of overlapping and needless investment. I remember instances where there were four pole lines in a single street. The result was none of the companies survived and a great many stockholders lost money.

The suburban and small communities must have their distribution systems tied together by longer transmission lines. That, of course, is the only hope for permanent electric service in the small communities. The business opportunities are small. In most of them the residence portion is the greatest part of the income. People take the interurban or the steam cars and do their trading at the county seat or in some larger town; so the greater percentage of the income is the residence lighting. Contrast that with a very large community. The entire residence income in Chicago is not sufficient to meet the pay rolls of the Commonwealth Edison Company. In other words, of the four divisions, residence lighting, commercial lighting, industrial power and railroad power, the residence part of it is the small end of it, while in a small town or village the residence income must always be the largest. Therefore particular care must be taken, as has been emphasized, both in the papers and in the discussion, in the expenditures that mean a fixed charge every year, because every dollar that is put into the property means ten or fifteen cents not one year or two years but every year.

FORTIFICATION

By Capt. H. B. Sauerman, M. W. S. E.

*Presented May 1, 1916.**

MODERN TRENCH WARFARE.

The modern rifle, the machine gun, the howitzer and the new field gun are responsible for the modern trench warfare. These powerful weapons make it impossible for troops to give battle in the open field without suffering tremendous losses. Cover and concealment, either natural or artificial, are two of the main requirements of a modern battlefield.

Trench warfare has brought out no new developments. Advancing by sapping and parallels, mining and the use of hand grenades has not changed in principle; the application, however, has been more extensive with modifications to meet the new conditions and the more powerful weapons.

Trench warfare is generally divided into four stages:

1. The first stage is that in which the two armies come in touch with each other and after finding the open attack impossible, finally intrench. At this stage one army may take the defensive and the other army the offensive, or each army may attempt to attack the other.

2. In the second stage they attempt to capture each other's trenches. To accomplish this, attacks are carried on over the open space between trenches and if these fail each army advances by moving forward at night and by intrenching in the new position.

3. In the third stage the armies advance upon each other mostly by digging trenches to the front. This method of advancing is called sapping and the trenches leading forward, usually in zigzag fashion, are called saps. The heads of these saps are connected by trenches parallel to the original front or trench. Attacks in the open are also attempted at this stage.

4. In the fourth stage the trenches of these armies have come so near to each other that they can no longer advance by sapping. The advance by this method is stopped by the use of hand grenades and bombs which each army, without leaving the cover of its own trenches, can throw into the trenches of the other army. At this stage the tunneling is carried out underneath the ground, the trenches are blown up and the craters caused by the explosion are occupied and are put in defensive condition by the army capturing them.

To illustrate this system of warfare, plate 1 has been prepared. In order to explain this system we assume that a Red force is invading the territory of a Blue force. The Blue force is encamped at the foot of Blue Hill and the Red invasion will proceed over Red Hill. When the Red advance guard reaches the crest of

*Paper read by Lieut. Guilfoil.

Red Hill it at once sends a message back to its commander advising him of the presence of the Blue force. The Red commander orders skirmishers to take position at foot of Red Hill and open an attack on the Blue Force. The Blue force answers with a vigorous infantry fire and as the Red commander sees the firing line of the Blue force receive heavy reinforcements, he at once decides to bring his artillery into action to support the infantry fire. His batteries are placed in rear of crest of Red Hill so that they cannot be located from Blue Hill and opens fire on the Blue force wherever they appear in masses. When the Red artillery is put into action the commander of the Blue force brings his artillery up near the rear crest of Blue Hill and attempts to silence the artillery of the Red force by bringing his artillery fire to bear on the Red artillery. The Red artillery changes its fire and attempts to silence the artillery of the Blue force.

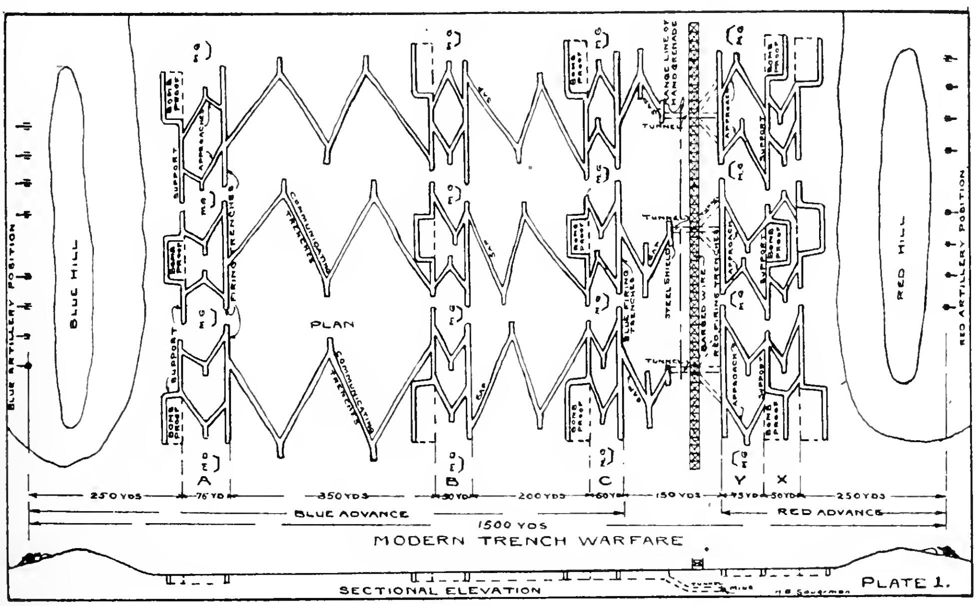


Fig. 1.

Attempts are now made by both infantry forces to advance and gain ground by rushes, but they find that their losses are considerable, as both forces bring a heavy infantry and machine gun fire on any section that rises and attempts to move forward. After several unsuccessful attempts the men throw themselves on the ground and place their knapsacks or blanket rolls in front of them and continue firing. While some of the men are firing others unstrap their intrenching tools and start digging a shallow trench, throwing the earth in front of them for protection. Each man digs for a while and then fires at the enemy while his nearest neighbor digs. Meanwhile the artillery duel continues.

When night and darkness come both forces work with large

intrenching tools. The Red force intrenches in position "X." They dig a firing trench and another trench 50 yards in rear of the firing trench. In this rear trench they also construct bomb proofs. The two trenches are connected by zig-zag approaches. The Blue force constructs similar trenches, but the distance between their trenches is 75 yards. In digging these trenches concealment is given the greatest consideration. The omission of the parapet entirely or very low parapets with the sod placed back on the face toward the enemy is common practice. Dummy trenches, made from the excavated earth, are used to deceive the enemy.

When daylight comes the artillery promptly opens fire on the trenches and the infantry forces take to cover in the bomb proofs. Only a small trench guard remains in the firing trenches. The men occupy themselves during the day, strengthening and improving their respective entrenchments. The machine guns are usually placed slightly in rear of the intervals between trenches and on the flanks. They are almost always masked and under cover so as not to attract the hostile artillery fire.

The second night the Blue force sends out skirmishers about 500 yards in advance of their position. The Red commander decides not to advance until heavy reinforcements arrive.

To avoid a surprise attack he sends out small reconnoitering parties, who discover the Blue skirmishers about 300 yards from their trenches. They open fire on the skirmishers at once and are reinforced by additional men from the firing trenches. This intermittent fire is kept up the entire night. The Red force finds it to their advantage to advance their line 75 yards and to convert the first firing trench into a support trench with bomb-proofs, as shown at "Y." The Red force also constructs wire entanglements in front of their position.

The Blue force constructs a second line of trenches at position "B," about 400 yards in advance of their first position.

At daybreak both forces start strengthening and improving their positions. Both positions are bombarded intermittently during the day. The Blue artillery brings a heavy fire on the wire entanglements of the Red force with the intention of destroying them. The Blue infantry force takes advantage of all possible means to advance their positions and, therefore, start sapping operations, which they find necessary, being in close range of the Red infantry fire. Several hours before dusk the Blue artillery opens a heavy fire with high explosive shells. This fire is a steady fire directed on the Red trenches and wire entanglements. When darkness sets in this fire ceases.

Shortly after dark the trench guards of the Red force hear noises made by the Blue force cutting the wire entanglements. The Red force at once opens fire. The Blue force rushes forward with fixed bayonets. Many are shot down as they come up to the Red trenches. A portion of the Blue force finally succeeds in capturing a section of the Red trench, but their success is of short dura-

tion. The Red support is brought up and a machine gun on the flank of this captured trench brings a terrific fire into this trench. The men of the Blue force, who are not killed or wounded in this trench, escape in the darkness. Silence reigns for the rest of the night. In the morning it is found that the Blue force has constructed another set of parallel trenches at position "C." They have also connected these trenches to the saps which were started the preceding day by regular approaches.

The artillery cannot fire on the trenches now as the two forces are too close and the danger of hitting their own forces is very great. The Blue force now starts sapping operations and continues to a short distance from outside of the range of hand grenades and bombs. At the head of these saps small parallels are dug. The top of these parallels are covered over with logs and earth and a small steel shield with loop holes is placed in front of them. Sharpshooters placed in these parallels act as a guard and shoot at any Red man who dares bring his head above the trenches.

From these parallels the Blue force starts a tunnel, digging forward and gradually downward. This tunnel is about 4 ft. 6 in. high by 3 ft. 6 in. wide. When a depth of 15 ft. is reached the tunnel is continued on a level. When the tunnel has passed underneath the barbed wire entanglements, small branches are run to right and left of main tunnel. These branches are made 3 ft. 6 in. by 2 ft. 6 in. The smaller the tunnel the less noise and the quicker completed. When under the Red trenches a large earth auger (consisting of a heavy bar and large gimlet) is used to dig holes for the mines. Melinite is then placed in these holes and the Red trench is blown. This is usually done at night. Immediately when the trench is blown the Blue forces rush forward, the Red forces fire illuminating shells, when the Blue force rushes into the craters made by the explosion. The Blue engineers with picks and shovels and revetment, construct a parapet and also construct approaches back to their position. The ends of crater are blocked as only part of trenches are captured.

The Red force, after recovering from the shock, comes to each side of trench occupied by Blue force with the object to recapture same. They are met with a heavy rifle and machine gun fire and are forced to withdraw. The Blue force will then attempt to capture the balance of the Red trenches by sapping and mining as described above. The Red force will countermine and endeavor to drive out the enemy and thus the struggle continues until one force or the other are practically exhausted and are driven or blown out of the trenches.

The hand grenades used in this warfare consist of hollow receptacles filled with high explosives. There are two types: the percussion type, which has a fuse arranged to explode the charge when it strikes an object. The other type has a time fuse which is lighted before grenade is thrown.

A small mortar is also employed, which is aimed almost straight

in the air and will drop the small shell or bomb almost vertical into the enemy's trench.

For sapping the German army has now devised a digging or boring machine, with which they are able to accomplish the sapping operation in a very short space of time.

Plate 2 shows a detailed sketch of the tunneling and mining operation. This sketch is very clear and requires no further explanation.

FORTIFICATION IN MODERN WAR.

The extensive use of trenches and field fortification during the Russian-Japanese War and the great European War proves conclusively that the proper and intelligent use of trenches and field fortifications, both for defensive and offensive operations, will have a most important bearing on the results of a modern battle.

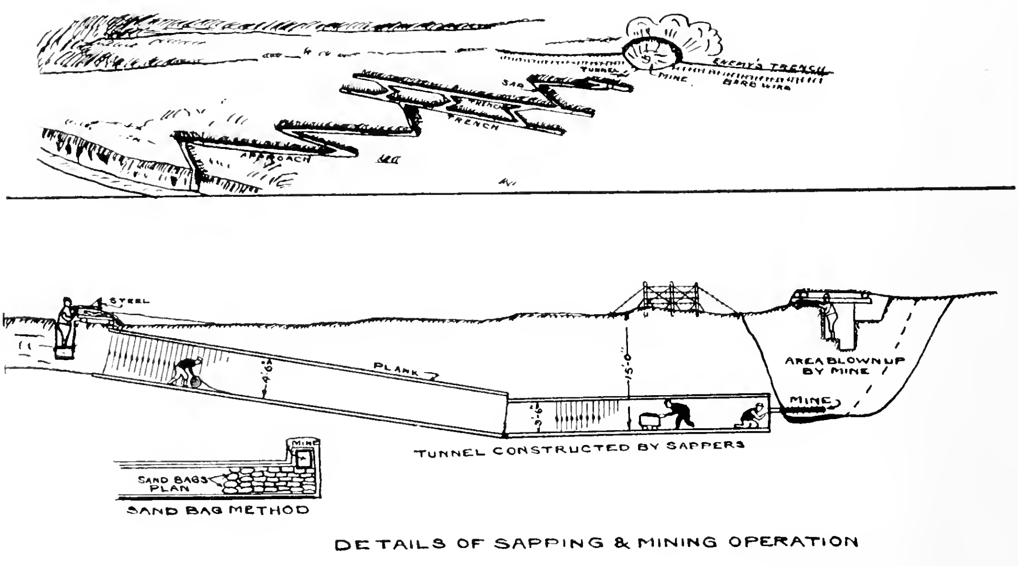


Fig. 2.

It may be accepted as a principle, established by experience, that a line of men can not remain stationary under fire without cover, natural or artificial. This is true in every phase of action, whether advancing, retreating, or standing on the defensive. Cover at all times is desirable; on the move it may be dispensed with, at a halt never. In some cases the cover will be partly natural and partly artificial, i. e., partial natural cover artificially improved. In a majority of cases, however, conditions of fire efficiency and concealment will require a line to be placed where it could not possibly live without artificial cover. Another principle, which may be accepted, is that on the offensive the line must determine the general position of the cover and not the cover the position of the line. The position of the line at any moment of a battle depends on tactical considerations and the progress and incidents of the fight. To prepare

trenches in advance, except for defensive occupation, is to attempt to predict the future. It follows that all troops, not in a defensive attitude, must prepare their own cover after occupying a line or after they are halted. The importance is paramount of having available for instant use on every firing line the appliances and training to enable the men to get sufficient cover in the shortest possible time. This involves not alone the training of the men to dig with the tools provided, but also the knowledge and skill of their own officers to locate the trenches to the best advantage. There is no time to wait for instructions or advice from the outside.

Permanent fortifications have an inestimable value as a refuge for a defeated army to rally under, as a defense to communications, as a protection to the flank of an army, as a protection of a frontier, and as a threat on the flank or rear of an advancing foe.

Sea coast fortifications have a great value in protecting sea coast cities, harbors, naval bases and other strategic points along the sea coast.

FIELD FORTIFICATION.

Field fortification is an aid to tactics and it should be constantly borne in mind that fortifications are designed for tactics, not tactics for fortifications. A thorough study of the general tactical situation is the first and most important step toward a successful application of fortification. The following questions will arise in the study of the situation:

1. What is the general plan of operation?
2. What part are the fortifications to take in the general plan of operation?
3. Will the fortification be used for defensive operation only?
4. Will the fortification be used for offensive operation only?
5. Will the fortification be used for combined offensive and defensive operations?
6. What will be the strength of the attack infantry, cavalry and artillery?
7. What light arms, equipment, machine guns and artillery will probably be used by the enemy?
8. From what direction is the attack expected?
9. At what time is the attack expected?
10. What are the natural features of the ground at place where attack will take place?
11. What is the available armament and available strength of garrison for the fortification?
12. What are the available lines of retreat to a new position should the enemy's attack be successful?

It will not be possible to obtain all of the information as outlined above. Information relative to the strength and armament of the enemy, time and place of attack, etc., will in many cases be very vague and unreliable. All available means must be used to secure as much information and as reliable information as can pos-

sibly be secured. The time for securing information will usually be very short, and for this reason the judgment and reasoning power of the officer must be used to the fullest extent in determining many facts.

The work of Field Fortification may be divided as follows:

1. The general location of the fortification.
2. The division of the fortification into sectors and the garrison for each sector.
3. The division and disposition of the support and reserve.
4. The machine guns and their disposition.
5. The artillery position.
6. The disposition of the cavalry.
7. The trench trace and profile.
8. The overhead cover.
9. Loop holes.
10. Drainage.
11. Artificial concealment.
12. Clearing the ground.
13. Obstacles.
14. Dummy trenches.
15. Execution of work.
16. Observation, telephone and water supply.

THE GENERAL LOCATION OF FORTIFICATION.

The requirements of a well fortified position are:

1. Concealment.
2. Good field of fire.
3. Natural or artificial cover.
4. Obstacles for retarding or directing the course of enemy.
5. Easy and concealed communications for practical movements of your troops.
6. Obstructed and unprotected communications for enemy.
7. Easy digging soil; free from rocks and roots.
8. Sufficient height to give good view over ground over which enemy will advance.
9. Natural flank protection.

Concealment is of the greatest importance. This does not only include the trench and parapet, but also the obstacles in front of same, for if these are not concealed they will assist the enemy in locating the trenches in rear and the hostile artillery will further destroy same. Formerly the field of fire was given the greatest consideration. The war of today has demonstrated that a field of fire of 100 yards will be sufficient if it can not be extended without loss of concealment. Low parapets, the omission of parapets, a background, avoidance of sky-lines, narrow trenches, covered trenches, rounded crests and corners and the concealment of disturbed soil are all very effective in securing concealment.

For concealment against observation from aeroplanes and also

horizontal concealment, the author suggests a canvas covered trench. The canvas can be painted any color to suit the surroundings, or by scattering lightly grass, earth or other matter over the canvas almost perfect concealment can be obtained within a short space of time. The canvas covering will further protect the garrison from rain and the direct rays of the sun. Figure 1 on Plate 3 shows an ordinary firing trench provided with the canvas cover, as suggested by the author. Figure 2 shows a double tier firing trench provided with this same covering.

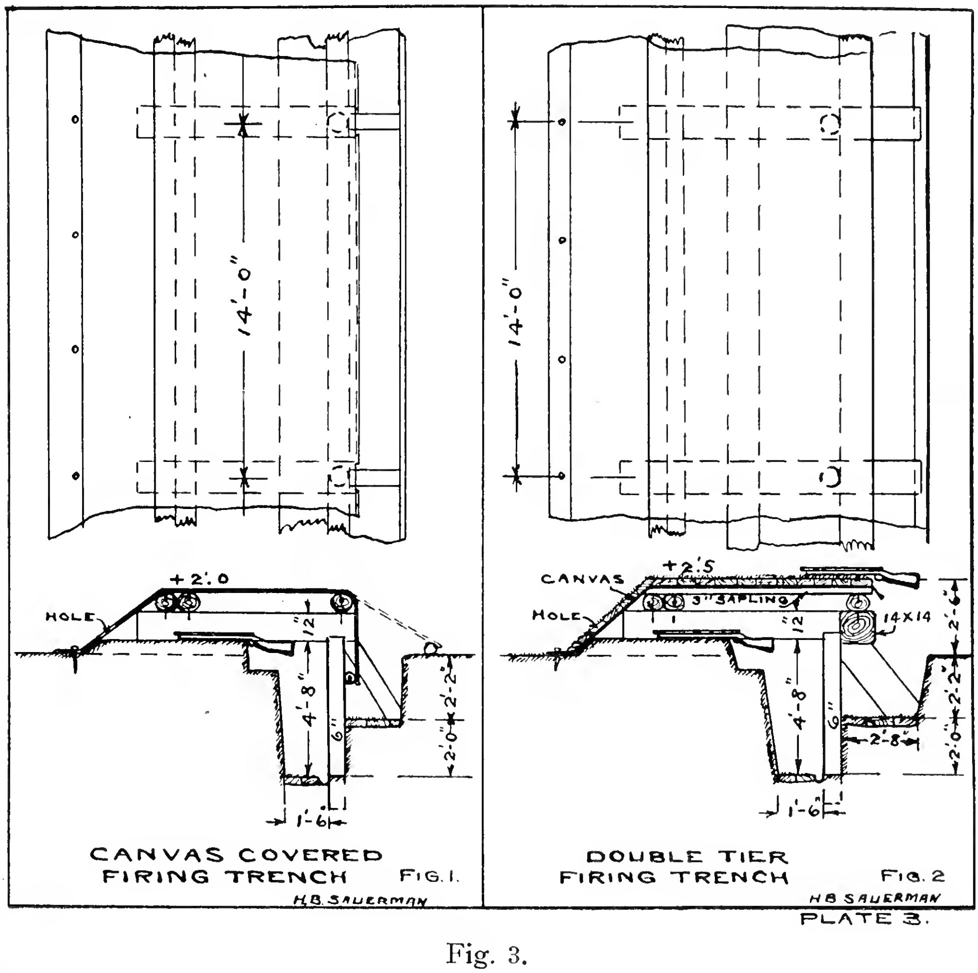


Fig. 3.

The field of fire must permit of the full use of the defenders' weapons. This requires a level or slightly sloping open space in front of the trenches for 100 to 700 yards. A grazing or parallel to the ground fire is the most effective. Fire delivered at a considerable angle with the line of trench is not very accurate. The limiting angle for good results is about 12 degrees. Trenches should, therefore, be fairly straight and at right angles to the fire.

Cover, either natural or artificial, is essential for the protection against infantry or artillery fire. Natural cover is usually obtained

behind crests of hills, in ravines, dry river beds, etc. Artificial cover is usually obtained in sunken roads, behind road and railroad embankments and in dry ditches or special trenches.

Obstacles for obstructing or directing the course of the enemy consist of marshes, rivers, valleys, cliffs, hedges and forests with heavy undergrowth. All these natural obstacles may force the enemy to attack only from one line and direction. The defender will then have the advantage to concentrate his entire force and means at the point of attack and prepare the position in advance. Where the enemy can be forced to attack over a narrow well swept front, the attack (everything else being equal) is almost certain to fail.

Easy and concealed communications can be obtained behind rising ground, through woods, through ravines, through large standing corn, etc. High sites furnish better protection for communicating trenches than do low sites, but this advantage of the high site is oft'times offset when the defenders are compelled to deliver an ineffectual plunging fire. Where natural concealment for communications can not be obtained artificial zig-zag or traversed communicating trenches must be built. Cover trenches for supports and reserves must be constructed in locations where the country is flat.

Where it is possible, the enemy should be forced to attack over difficult ground, requiring crossing of streams, etc., and where he will be exposed as much as possible, where his fire can not be developed and where his movements will be impeded.

Easy digging soil, free from large stones and roots, is very desirable where the time is very limited for the construction of trenches.

Authorities differ regarding the height of a position. It is desirable to have a certain amount of command for a defensive position. This height need only be sufficient to give an unobstructed view over the ground in front. In flat open country this height may be very little. The slopes to the front should be gentle and evenly sloping. A strong defensive position is one where one or both flanks are protected against attack by natural or artificial obstacles—rivers, deep marshes, mountains, etc., form good natural obstacles for protection.

It is very apparent that very rarely a position will be found which will meet all of the conditions and requirements as outlined, but it is also very evident that the position which meets most of the conditions and requirements will be the most easy to defend. The officer, should, therefore, carefully study his position accordingly, for upon the selection of the position may depend the results of the battle.

THE DIVISION OF THE FORTIFICATION INTO SECTORS AND THE GARRISON FOR EACH SECTOR.

Field fortification, for tactical and administrative reasons, should be divided into independent sections of such size as can be well commanded by one man.

Such a division is an aid to tactics in that it allows the tactical units with their supports, reserves, supply, etc., to be kept together, and the duty and responsibility of attending to the many details can easily be divided by the commander among the subordinate officers. It is very apparent that a better field control will result with such an arrangement, and it is also very evident that such a division will aid the administration and supply department in the same manner. To illustrate the arrangement of a modern field fortification sector, Plate 4 has been prepared. Briefly, the arrangement, as outlined, is as follows: Firing trenches are designed for full company units. A small trench guard is always stationed in the firing trenches. This may consist of one platoon or less in case of artillery bombardment. In case of threatened infantry attack the other platoons of each company which are stationed in the bomb-proofs are rushed forward through the communicating trenches and take their place in the firing trench.

When the entire first battalion is in the firing trench, the second

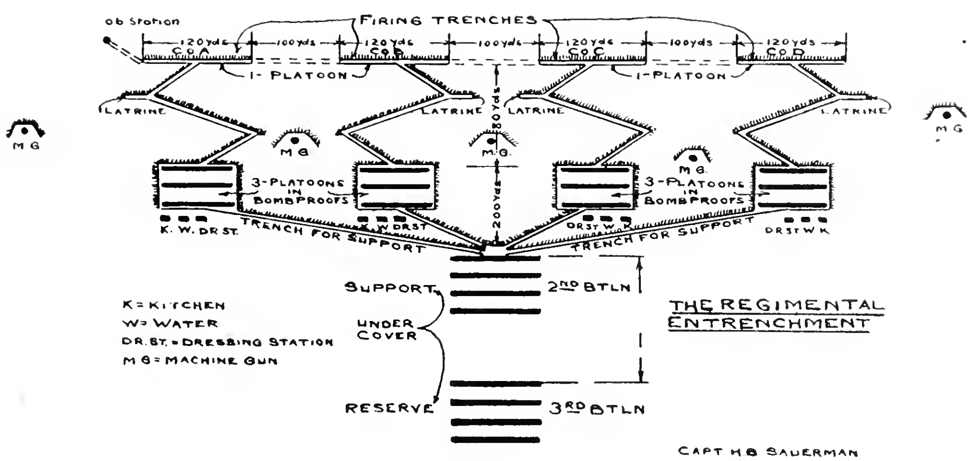


Fig. 4.

battalion moves up into the support trench and in the bomb-proofs These bomb-proofs are loop-holed to permit of firing to the front and flanks. In case of capture of the first firing trench, the first battalion will fall back to the support trench and there combine with the second battalion to stop the enemy's advance; under normal conditions the second and third battalions remain under natural or artificial cover and occupy the trenches only when conditions require it. When conditions require it the arrangement can be modified so that two battalions can be placed in the firing trenches with only one battalion in reserve. The machine guns are placed approximately as shown. In this location—they are in position to deliver a fire between the intervals of the firing trenches and they can also be rushed forward to deliver a flanking fire attack on the firing trench in case it is captured and occupied by the enemy. The machine guns can also be placed so as to protect the flanks of the

outer firing trenches. All machine guns should be masked or concealed so as not to attract the hostile artillery fire.

THE DIVISION AND DISPOSITION OF THE SUPPORT AND THE RESERVE.

Major W. W. Harts, in his excellent work, "Notes on Field Fortification," in the Professional Memoirs, gives the following information regarding the garrison, support and reserve:

"From one-quarter to one-half of the entire force should constitute the general reserve and the remainder be distributed in the various sections of the front as needed. In each section it is advocated that about one-quarter to one-half of the force assigned to it should constitute the section reserve, and of the troops remaining about one-half or two-thirds should be supports. About one-fourth to one-sixth only of the section's force will actually be in the trenches before being attacked. It seems to be desirable to reduce the force of men actually in the trenches to the smallest number consistent with safety. No exact proportion of reserves and supports can be given for all cases and the foregoing is only stated as a guide in forming one's own decision, which must always depend on the conditions peculiar to the ground, including the shape of the front, whether straight or curved, the size of the garrison, the enterprise of the enemy and the interior communications.

"But room in the trenches must usually be made for all the troops in the section, including perhaps space for some of the general reserve, so there must be some calculation made as to how much trench must be built or how much front can be occupied.

"Trenches must always be able to furnish enough aimed rifle fire to stop any ordinary infantry attack across the open space in front. It is plain that this will vary greatly in different terrain. One might suppose that the enormously increased power and rate of fire of the modern rifles had lessened the number of rifles necessary, and that the old rule of thumb of one man per pace of firing line is no longer required. Such density is no longer necessary, except perhaps for a short time for repelling assaults after the attacking troops have managed to bring a large force within close assaulting distance. At such times the maximum amount of fire possible is needed. Men can not use their rifles accurately if occupying less space than one pace of the front. This may then be adopted as a maximum density required for any part of the front where a close attack may be delivered. This assumes that a part of the general reserve is on the line. At other places less hard pressed more length of trench and less density will be possible. An English authority has even stated that one man to every eight or ten paces is enough to check any infantry assault on a well chosen position, or including reserves and supports from two to five paces per man. We may safely conclude that from 1 to 4 yards per man, including sectional reserves and supports, are limiting estimates depending largely on the ground. The density suggested in our field service

regulations, including supports and local reserves, is one man per yard, giving a front of 750 yards for the battalion, including intervals of 100 yards between companies, 1,500 for the regiment, and 4,500 for the brigade. The judgment of the officer as to the strength required will have to be exercised in each of the larger parts of the line in order to have it fairly balanced, increasing the density in some places and decreasing it in others."

THE MACHINE GUNS AND THEIR DISPOSITION.

Machine guns are now recognized as one of the most potent factors in battlefield operations. Our Field Service Regulations, 1914, Par. 34, gives us the following information:

"Machine guns are emergency weapons. They are best used when their fire is in the nature of a surprise to the enemy at the crises of combat. Their effective use will be for short periods of time—at most but a few minutes—until silenced by the enemy. When engaged they must be used to the limit of their effective capacity. On the offensive they find their use in assisting the attack to obtain fire superiority temporarily lost and against lines of trenches which are to be assaulted. In the defensive they are used against large targets visible for a short time only, and on advancing lines of the enemy's infantry within the short and mid ranges. The effect of the enemy's fire, particularly his artillery fire, on machine guns, is lessened by their employment in small groups."

In event of an assault they enable a heavy fire to be developed at a point where the enemy is strongest, provided the machine guns are placed so as to admit of their free use. For the defense of flanks of both infantry and artillery, for the defense of ditches, for positions where infantry would be visible or liable to enfilade fire, the machine gun posted behind natural cover or other concealment will give excellent service. Machine guns are placed between intervals of trenches as shown in Plate 4 and also on the flanks of infantry and artillery positions. They should be well concealed and the emplacement so constructed as to afford a maximum protection to the gun detachment consistent with the free use of the weapon. Splinter-proof overhead cover is desirable and should be provided wherever possible. Shelter should be provided for both gun and detachment when not engaged. It will sometimes be found to advantage to connect emplacements by communicating trenches. Fig. 1, Plate 5, shows a Single Machine Gun Emplacement. Fig. 2 shows a Double Machine Gun Emplacement.

Lieutenant Henry J. Reilly gives the following report regarding the value of machine guns in the present European war:

It is particularly in the defense of an intrenched position that machine guns are useful. Here, as in a fight in the open field, they must not open fire too soon, or the hostile artillery will wipe them out. Therefore, they generally remain silent until the enemy's infantry comes out of its trenches and starts across the intervening

space in its endeavor to capture its opponents' trenches. Then the machine guns open fire and keep it up until the last of the enemy left alive or unwounded have run back into their own trench or until captured or put out of action by a hand grenade if the attack is a success.

The Germans frequently arrange their trenches so that if occupied by the enemy a machine gun can fire down them, thus enfilading him and driving him out. If the configuration of the ground will permit it, they place most of their machine guns, not in the first line of trench, but in some position back of it. This is done to avoid probable destruction by the heavy shelling to which a trench is subjected by the enemy's artillery before an attack is made.

In accordance with this principle, where the Germans have been able to prepare a position ahead of time, they pick out a gentle slope and put three lines of trenches on it. The machine guns are placed in the last line, thus being able to shoot not only over the first two lines at any approaching enemy, but making a strong third line very

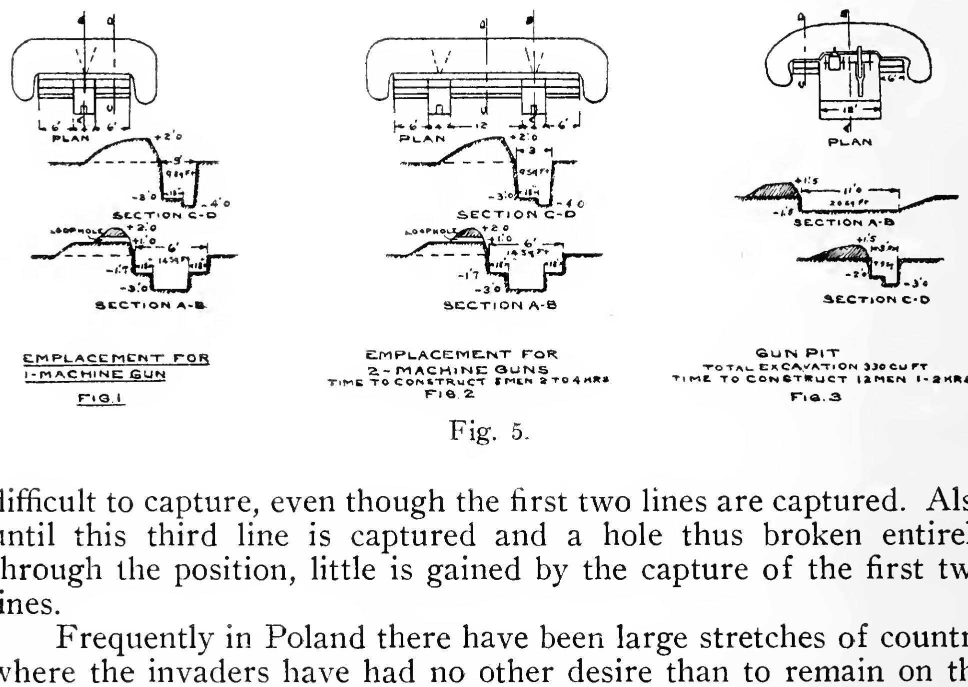


Fig. 5.

difficult to capture, even though the first two lines are captured. Also until this third line is captured and a hole thus broken entirely through the position, little is gained by the capture of the first two lines.

Frequently in Poland there have been large stretches of country where the invaders have had no other desire than to remain on the defensive. In these stretches the Germans strongly intrenched and garrisoned the important points. Between these points they constructed several lines of trenches, each with a very wide barb wire entanglement in front.

These trenches would have comparatively few troops in them, but a considerable number of machine guns. While a Russian attack might succeed in breaking through most of the entanglements in spite of the machine gun fire, it would take them so long that the German reserves from central points in the rear of the line would have ample time to get up.

THE ARTILLERY POSITION.

The artillery position is usually selected by the chief artillery officer after he learns the general situation and requirements from the commander.

Artillery positions are generally in rear of the intrenched infantry positions and are concealed from view usually by natural cover. When conditions permit, the artillery should be placed in a somewhat commanding position. Due to the perfection in firing by indirect laying, guns are now usually placed in rear of the crest of the hills. The advantage of such a position is easy concealment and easy concealed withdrawal, both of which are more important than direct fire. Concealment and mobility are in fact the most important factors. Dispersion is very necessary to reduce the hits of the hostile artillery, and with the improved field telephone system, guns can be scattered over a wide area without the loss of control. There should be numerous alternate emplacements, with casemates for the protection of the men. This will allow changes of position with a minimum loss of time. Positions should be selected to furnish a concentrated cross fire on all possible lines of advance of the enemy. Whether the heavy guns should be placed to the front or to the rear depends very much upon the enemy 's armament; if he has only the small caliber guns, the large guns may be kept in the rear; if the enemy has large caliber guns it will be necessary to place the heavy guns to the front to prevent him from building his batteries.

Good sites for observation stations are a prime necessity. They should be well concealed and connected by telephone to the different battery commander stations. Where it is possible, emplacements should be connected by concealed approaches.

The light field guns, which in practically all armies are about three-inch, are generally found in the zone from 2,000 to 4,000 yards from the enemy's trenches. The heaviest guns, such as the 305 millimeter (about twelve-inch) howitzer, are found at from 6,000 to 8,000, or even more, yards from the enemy's trenches.

The guns of the intermediate caliber, such as ten-inch howitzers and fifteen centimeter-rifles, are found somewhere between the light field guns and the heaviest ones.

The Austro-Hungarian 305-millimeter howitzer has been extremely efficient throughout the war. A large part of the work credited by the allies to the 420 millimeter has in reality been done by the 305. One of the marked features of this gun is its mobility.

The gun, the carriage in two parts, and a steel platform on which the gun and carriage rest during firing, travel on four steel trucks with heavy wheels, which are pulled by one or more traction engines, depending upon the state of the roads.

When the firing position is reached, the ground is leveled, the steel platform put down, and the gun and carriage mounted on it.

The 3-inch field gun, the 6-inch long range heavy guns and the 5-inch howitzer and mortar are usually employed in the field fortification.

The mortars and howitzers are usually located in retired position on the reverse side of hills, in ravines, etc.

In addition to the heavier guns, the 1-pound automatic and the 3-pounder and 6-pounder rapid fire guns are employed to good advantage. In case of assault they will bring a heavy fire to bear on the enemy.

Fig. 3, Plate 5, shows a very simple and easily constructed gun pit. The pit can easily be modified to meet different conditions and the low parapet admits of easy concealment. It was used extensively by the Russians in the Japanese War.

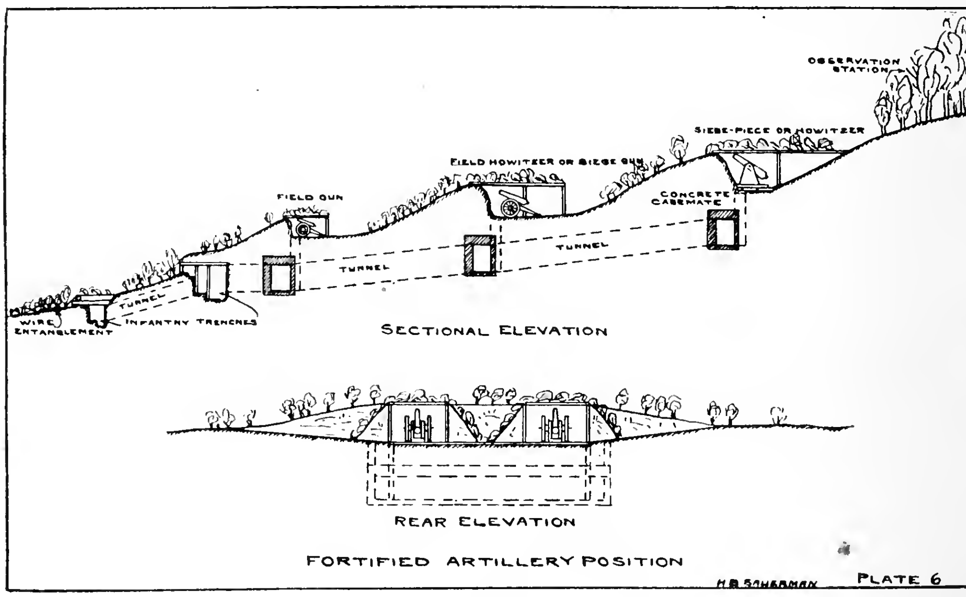


Fig. 6.

Plate No. 6 shows a fortified artillery position on the front slope of a hill. Such a position is a difficult one to conceal and further makes it very difficult to change position without being observed by the enemy. Brush, canvas, trees, sunken roads and dry ditches will oft'times help to overcome these disadvantages. It will be noted that the guns shown in this plate are all firing over the infantry trenches. This is a very common practice in the present European War. The guns should be placed at least 600 yards in rear of the infantry position so as to protect the artillery position from flank and rear attacks and further not expose the infantry to loss from premature bursts. For the sake of showing the gun positions clearly, they are all shown in cross section. In actual practice these guns would not be placed one directly in rear of the other, but would be widely scattered.

THE DISPOSITION OF THE CAVALRY.

Cavalry can render valuable service in connection with field fortification by the performance of the following duties:

1. Reconnoitering the enemy's position and securing information as to his strength, armament, disposition of troops, etc.
2. Delaying the enemy's advance so as to give the troops sufficient time to dig their trenches.
3. Selecting and holding strong defensive positions in advance of the infantry.
4. Protecting the flanks of a fortified position.
5. Threatening the flanks of the enemy and forcing him to attack along certain lines.
6. Clearing the ground by tramping down crops, such as standing corn, etc.
7. Performing demolition work.

Cavalry in modern war will seldom be called upon to make mounted charges. It has the great advantage of mobility. Infantry carried by motor trucks does not have the mobility that cavalry has, because the trucks are confined to good roads and also on account of the small number of trucks available.

The cavalry in the present European War is mostly employed in seizing strong positions in advance of the infantry and holding these positions by fighting dismounted until the infantry arrives. When the Allies were trying to extend their lines to Antwerp and the Germans were trying to reach the Belgian coast in October, 1914, the cavalry of both armies played a most important part in the region of Lillie and Ypres.

Cavalry played a most important part in the Allies' retreat and the German's advance to the Marne.

Cavalry is also employed in filling gaps between infantry units. Owing to its great mobility, it can reach decisive points long before it would be possible for infantry to do so. The present war shows many instances in which cavalry filled important gaps.

THE TRENCH TRACE AND PROFILE.

Prepared fortified lines of resistance will consist normally of successive lines of trenches or supporting points with intervals, the intervals being such that mutual defense by cross fires and flanking fires is assured. The supporting points will usually be groups of rifle trenches combined with natural topographical features. The intervals between trenches and supporting points will vary from 100 to 800 yards.

The flanks of a trench or a position will always be tempting points for the enemy's attacks and they should therefore be secured by resting them on impassable obstacles or, if this cannot be done, by echeloning them to the rear and placing reserve trenches close at hand.

Long trenches are not desirable even where the ground permits of their application, which it ordinarily does not. Any long trench once located by the enemy easily leads to the disclosure of the remainder. A long trench penetrated at any point will generally become untenable. For these reasons it is considered preferable to limit the length of a single trench to that required for a company and if a greater development of fire is needed, additional trenches of company, platoon or even squad length may be constructed. The several trenches of a group need not and generally would not be on the one line, but might be separated in depth as well as laterally.

The trace of a trench should follow a contour. Men standing about 11 paces apart may hold a tracing tape at the height of parapet. By looking all along the tape, it will be seen whether each part of the parapet will command the ground in front of it. If the command is greater than required, the parapet may be lowered or retired. Note also whether the longest trenches are on the sides of the easiest approach, if not trace must be modified. Fairly straight lines at right angles to the delivery of fire are to be preferred. If curves must be introduced they should have a radius of at least 20 yards. All trenches should be long enough to give an effective volume of fire. A squad trench 11 paces or 9 yards is about the minimum.

Tracing and profiling are not independent operations. The trace depends upon the profile and the profile upon the trace. The profile, however, is fairly well standardized while the trace must be determined by the circumstances and conditions. In field fortification the term trace usually designates the horizontal projection of the interior crest. This trace, as stated before, should follow a contour; if the contour curves, the trace should also curve; sharp angles should be rounded off so as to make them less conspicuous. Plate No. 7 shows a trace of a Battalion Supporting Point in accordance with the German Regulations 1910.

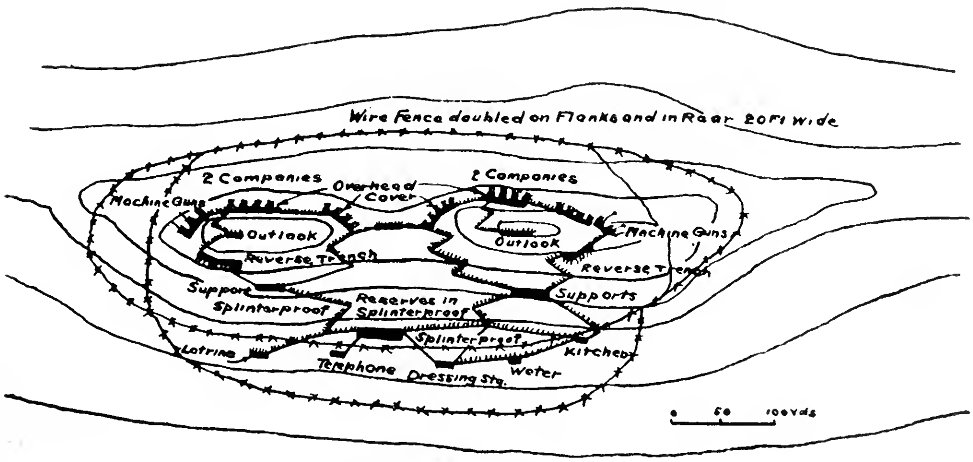
Due to the improvements in rifle and artillery fire, the high parapets and broad trenches of the past years have been replaced with narrow trenches with very low parapets or with parapets entirely omitted. If a parapet is used, the crest should not be over 18 inches above the ground and the surface should be a straight gentle slope, not steeper than 1 on 6. Both these conditions help considerably toward concealment. The front wall should be as near vertical as possible; this provides better shelter and helps the soldier when in firing position. An elbow rest of 9 to 12 inches is also an aid. Most authorities state that a height of 4 ft. 3 in. to 4 feet 6 in. from the bottom of the trench to the crest of parapet is necessary for a man firing while standing. The author's experience has been that 4 ft. 8 in. will better meet the average condition on account of the dirt along parapet being disturbed by movement of rifles, etc. Furthermore, in case of heavy rains the height of parapet

will be reduced. Should this height be too great for certain soldiers it can readily be decreased by throwing a little of the dirt to one side.

There is a practical limit to the narrowness of a trench. A trench narrower than 2 ft. can not be dug and used to good advantage. It is too narrow for two men to pass in it or for a man to sit with his back to the front wall; 3 ft. is the limit for this purpose.

Major Harts gives the following essentials of the profile:

First, a low bullet-proof parapet not over 18 inches high with a single gentle slope not steeper than 1 on 6 and an elbow rest 9 inches below the crest; second, a narrow trench with vertical or nearly vertical sides and of sufficient height to cover a man standing, and wide enough to sit in and permit another to pass; third, some



Type of
IDEAL BATTALION SUPPORTING POINT.
GERMAN REGULATIONS 1910
2 PLATOONS IN TRENCHES
2 " " SUPPORT
2 COMPANIES IN RESERVE
TRENCH ROOM FOR ENTIRE BATTALION 1 YD PER MAN
ABOUT 400 YDS LONG OVERHEAD COVER FOR 2 PLATOONS.

Fig. 7.

protection from enfilade or oblique fire by using traverses or special arrangement of the ground plan, and fourth, a bottom slope with a gutter for drainage. The following tables and information relative to range and penetration will assist in determining the necessary thickness of parapet:

RANGE.

Range	Rifle	Field Artillery	Heavy Artillery
	Yards	Yards	Yards
Distant	Over 2,000	Over 4,500	Over 6,500
Long	2,000 to 1,200	4,500 to 3,500	6,000 to 5,000
Effective	1,200 to 600	3,500 to 2,500	4,000 to 2,500
Close	Under 600	Under 2,500	Under 2,500

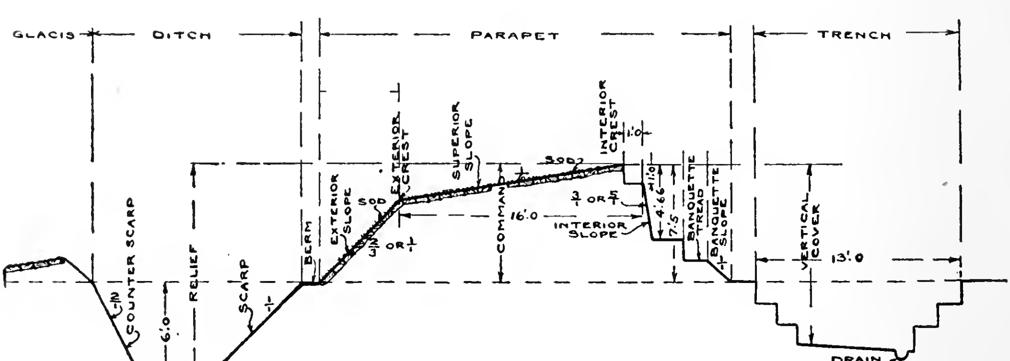
PENETRATION OF RIFLE BULLET.

	Inches	
	200 Yards	600 Yards
Commercial Steel	0.30	0.20
One-inch broken stone, gravel	4.80	4.28
Hard coal between 1-inch boards	9.00	7.00
Brick masonry, cement*	2.20	1.16
Brick masonry, lime*	2.40	1.14
Sand, dry†	18.18	11.96
Concrete, port, 1-3-5	3.00	1.86
Oak	26.46	12.46
Sand, wet	30.00	13.00
Pine	25.72	13.00
Earth, loam	30.00	16.12
Grease clay	60.00	32.00

EFFECT OF ARTILLERY FIRE.

Up to 3,000 yards, the 3-inch field gun, using high explosive shell, is effective against ordinary types of overhead cover for field trenches, brick buildings and stone walls 2 feet thick. It is ineffective against earthen parapets.

The heavier types of fieldguns and howitzers are effective against all kinds of field works, and protection against this kind of fire must be secured by concealment.



PROFILE OF FIELDWORKS

Fig. 8.

The thickness of ordinary earth required to resist penetration at usual battle ranges is 3 ft. for rifle fire, 10 to 24 ft. for field guns.

Plate No. 8 shows a profile of field works on which the names of the component parts are indicated. Plate No. 9 shows our standard profiles as outlined in our Regulations. Plate No. 10 shows a progressive trench profile adopted from German and English regulations.

*For Single shot.

†In sacks, about one-half these figures.

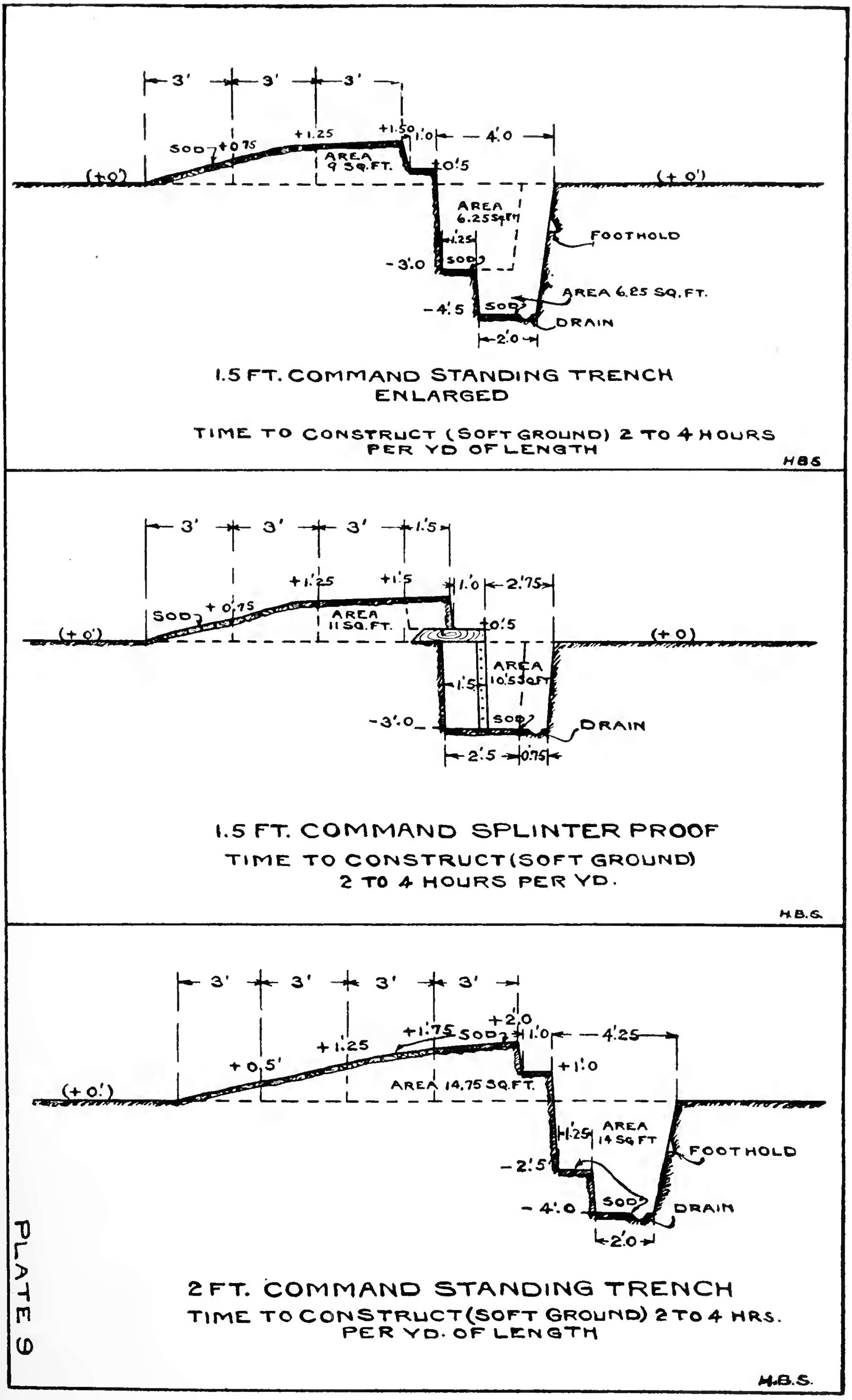

SOD
AREA 9 SQ. FT.
AREA 6.25 SQ. FT.
FOOTHOLD
AREA 6.25 SQ. FT.
DRAIN
1.5 FT. COMMAND STANDING TRENCH
ENLARGED
TIME TO CONSTRUCT (SOFT GROUND) 2 TO 4 HOURS
PER YD OF LENGTH
HBS
SOD
AREA 11 SQ. FT.
AREA 10.5 SQ. FT.
DRAIN
1.5 FT. COMMAND SPLINTER PROOF
TIME TO CONSTRUCT (SOFT GROUND)
2 TO 4 HOURS PER YD.
H.B.S.
SOD
AREA 14.75 SQ. FT.
AREA 14 SQ FT
FOOTHOLD
DRAIN
2 FT. COMMAND STANDING TRENCH
TIME TO CONSTRUCT (SOFT GROUND) 2 TO 4 HRS.
PER YD. OF LENGTH
H.B.S.
PLATE 9

Fig. 9.

OVERHEAD COVER.

Overhead cover should be provided wherever and whenever possible. This need not necessarily be of massive nature, but in many instances it need only be sufficient to give good concealment.

Our Engineer Field Manual gives us the following information regarding thickness of overhead cover:

For splinterproofs 6 to 8 inches of earth is necessary with a timber structure sufficient to carry the load. For bombproofs a minimum thickness of 6 inches of timber and 3 feet of earth is necessary against field and siege guns and 12 inches of timber and 6 ft. of earth is necessary against howitzers and mortars of a heavy siege train. A German military engineer recommends a thickness of earth equal to twice the depth of penetration of the shell before bursting and a supporting structure of sufficient strength to safely carry from 2 to 4 times the weight of earth coming on same.

Col. von Schwartz states that during the siege of Port Arthur

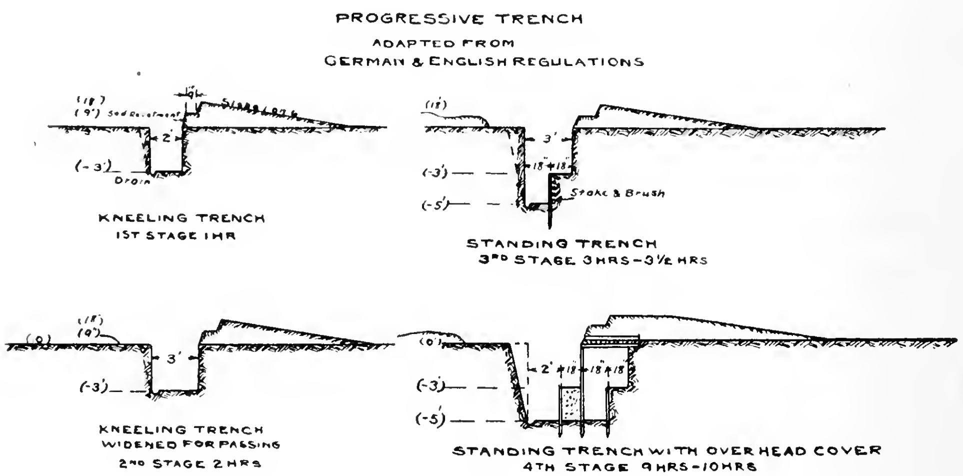


Fig. 10.

a 5-ft. thickness of clay tamped in one-foot layers and placed over a concrete roof successfully withstood the repeated action of a 6-inch shell. For concrete covering Colonel von Schwartz recommends a thickness of 9 ft. to resist the 11-inch shells, such as were used at Port Arthur.

Our sea coast fortifications are provided with a 10-ft. Portland cement concrete overhead cover.

An earth covering from 5 to 10 ft. in thickness placed over concrete roofs greatly assists in taking up the impact of the shell.

The German practice in the present war is to provide dug-outs from 25 to 35 ft. below the surface and in front of their trenches. These dug-outs are reached by half-galleries. Plate 11 shows two types of these dug-outs with galleries for same. The British provide recesses in their front trench walls, as shown in Plate 15.

LOOP HOLES.

The use of loop holes must be determined by the local conditions. The chief disadvantages of the loop holes are the reduction of rifles and the restriction of the fire to a frontal direction. Visible loop holes are very dangerous and to aid concealment the rear of the loop hole should be shut off from any light.

As concealment is one of the most important factors in trench warfare, the use of loop holes is very common in the present European War. The most serviceable form of loop hole consists of a pyramidal box made of 2-inch plank with a steel plate spiked on small end of same and pierced for fire. The steel ½ inch thick and the opening in same is about 2 inches by 4 inches. This opening is usually provided with a movable lid which closes the opening when not in use. This is known as the "hopper loop hole."

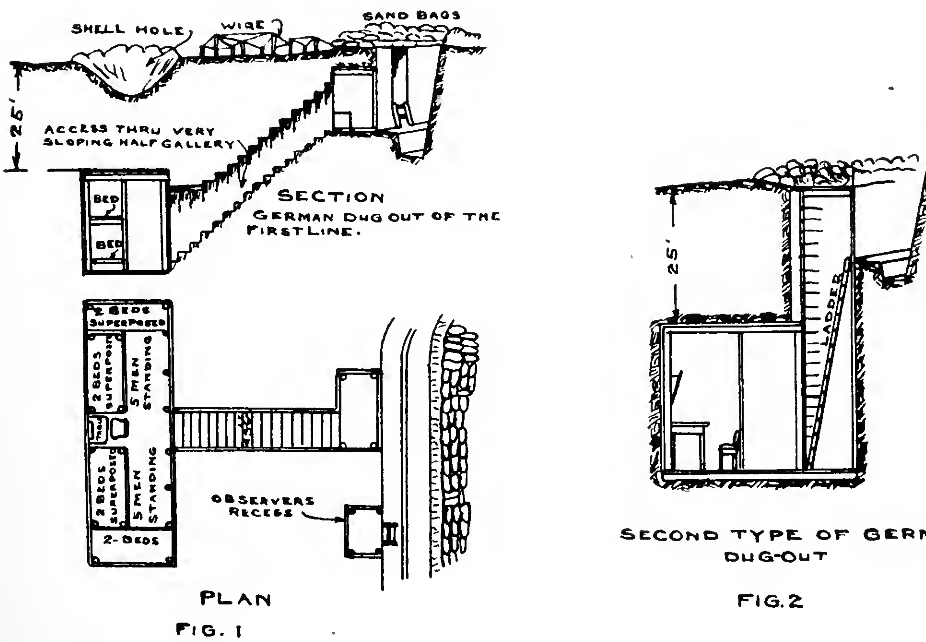


Fig. 11.

Loop holes can also be readily constructed with sod or sand bags.

Loop holes must not be closer than 1-yard intervals. If placed closer they will weaken the parapet. *All loop holes must be masked* so as to avoid discovery by the enemy. A continuous loop hole may be readily constructed by placing two 14-inch diameter logs along and above the parapet with supports 14 feet apart. The logs raised from 3 to 6 inches above parapet so as to give the men sufficient space to fire through. Concealment can be secured by throwing grass or dirt over logs so as to blend with the surroundings.

DRAINAGE.

The drainage of trenches is of great importance. When trenches are constructed under threatening weather conditions, or where trenches are constructed near the foot of a hill or in low level country, drainage becomes a prime necessity even if the trenches are to be occupied for only a comparatively short time.

Trenches should at all times be made as dry as possible. The floor of the trench should be made to slope backward to a small drainage ditch or gutter which carries the water to a sump or to a point where it can be disposed of otherwise. Hand-operated pumps or small power-driven pumps can ofttimes be used to good advantage. Provisions should always be made for excluding surface drainage when constructing trenches on the side of a hill. Fascines laid on floor of trench will aid very much in keeping the feet dry. Nothing will take the fighting spirit out of a soldier quicker than will wet feet or wet lower garments.

ARTIFICIAL CONCEALMENT.

With the extensive use of the high power weapons and the howitzers of small and large caliber, the question of sufficient thickness for both horizontal and overhead cover becomes a serious and difficult one. The author fully agrees with the school of military engineers who believe that the best protection lies in concealment and mobility. Even if the protection by thickness of cover alone would be advisable at times, the element of available time will enter into the problem and in many cases will not permit the construction of sufficient thickness of cover.

Low parapets, sodded parapets, the entire omission of parapets, avoidance of skyline, certain backgrounds, narrow trenches, curved traces and concealment of disturbed ground will aid greatly in securing concealment. Obstacles must also be concealed to avoid their destruction by the enemy's artillery and further avoid aiding the enemy in locating the position by means of the obstacles. Lighting systems should be of a flashing rather than of a constant nature.

The author again wishes to bring the reader's attention to his canvas system of concealment, as shown on Plate 3, for infantry trenches, and on Plate 17, for permanent fortification. Canvas will not only offer good concealment by giving it the color of the surroundings, but it will also furnish protection from the rays of the sun and from rain, sleet and snow.

Even the armored turrets could be concealed to good advantage by means of this material. The canvas could be made up in rolls so that it could readily be handled by two men.

CLEARING THE GROUND.

Clearing the ground to obtain a good field of fire should be given very careful consideration. A clear field of fire of 100 yards in front of the trenches will be sufficient if it cannot be extended

without loss of concealment. Large trees in standing position give less concealment than when lying on the ground. Thickets and brush can be cut down or burned. Large high-standing crops, such as corn, cane, etc., can readily be tramped down by cavalry or leveled with horses hitched to some kind of a drag. Special attention should be given to objects which will afford probable concealment for the enemy's artillery or machine guns. These objects should be destroyed. If the sacrifice of labor and time is not too great and good concealment is not sacrificed, a field of fire of 800 yards will ofttimes be found of great advantage.

OBSTACLES.

Obstacles assist in strengthening defensive positions.

Obstacles should form no shelter for the enemy.

Obstacles should be sheltered from the enemy's artillery fire wherever possible. Obstacles should be difficult to remove. Obstacles should not interfere with counter attacks.

Obstacles should be placed from 25 to 100 yards from the trench.

Obstacles should be concealed. This can be accomplished by scattering small pieces of brush over same but this brush must not be of such density so as to afford a screen for the enemy. Another effective method is to provide a shallow wide trench for wire entanglements, etc.

Col. Fieberger, in his work on Fortification, gives us the following information relative to obstacles:

"Obstacles are employed in connection with fortifications to protect the works from surprise, to break up the assailant's formations, and to hold his troops for a time under the accurate fire of the defender. They should be concealed from the assailant, they should neither give him cover nor conceal his movements, and they should be difficult to destroy. Obstacles may be placed either in front of or along the line of defense. If in front of the line, they are most effective if they are under the close infantry fire of the trenches, under close observation at night, near enough to the line of defense to compel the assailant to cease his artillery fire before his infantry reaches them, and far enough from that line to save them from destruction during the artillery bombardment which precedes the infantry attack. Obstacles along the line are either in the ditches of the fortifications or in the intervals between the works of the intrenched line. For passive defense the obstacles in front of a defensive line should be continuous; for active defense they are employed only in the defense of salients or key points."

Plate 12 shows different types of obstacles, including some of the latest types used by the German army.

DUMMY TRENCHES.

Dummy trenches are useful in diverting the enemy's fire. These trenches are usually constructed with the waste ground from the

regular trenches or they are quickly constructed by means of horses and plows. The appearance of these dummy trenches must be of such appearance so as to deceive the enemy, otherwise it is very apparent that they will fail in their purpose.

EXECUTION OF THE WORK.

Fortification, like all other work, should be executed in the shortest possible time and with the least fatigue of the men.

The officer must bear in mind that 2 hours of digging will leave a soldier fit for both fighting and marching, while 4 hours of continuous digging will unfit him generally for either fighting or marching.

In executing the work *the first step* is to mark on the ground the projection of the interior crest, sometimes called the firing crest. It may be marked continuously by stretching a line or by

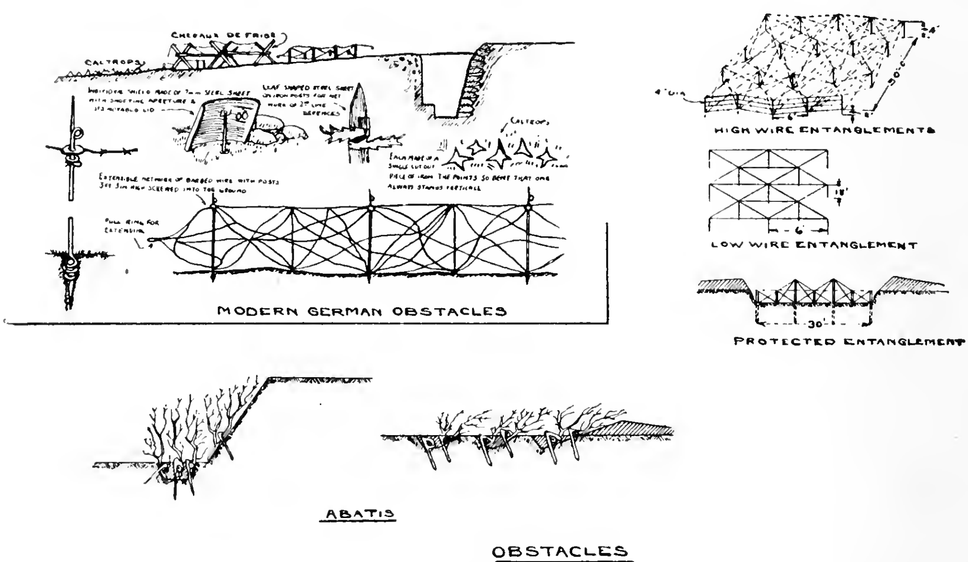


Fig. 12.

scratching the surface with a pick. The author suggests that a line be stretched at a height of the interior crest supported on stakes set 11 paces or approximately 9 yards apart. These stakes will mark the length of a squad trench with an allowance of 1½ feet on each side for a traverse. *The second step* is to determine the depth and width of trench and to check the height of parapet so as to assure a clear field of fire. *The third step* is to mark the toe of parapet and also lay out the ditch if one is required. This is best accomplished with stakes set about 2 yards apart.

Working parties should be made up so far as possible of entire organizations. A battalion should be ordered to send one, two or three companies; a regiment, one or two battalions, and a brigade, one or two regiments.

Work should be performed by complete units—this will greatly assist in control and placing responsibility. The author believes the

best results can be obtained by assigning one squad to each 9 yards of trench (this is the squad length, 1 yard per man and 1½ feet at each end for traverse) with a corporal in charge of each squad. The corporal is held responsible for the men and work performed. To place a detachment on the work, the organization comprising it approaches the tools in column of files, rifles slung, pass between the piles of tools, shovels on the right, picks on the left. Engineer soldiers at each pile hand tools to the men as they pass. The corporal or squad leader places himself alongside the rear file of his squad, he takes a shovel while the file on his side takes a pick. Each squad leader then conducts his squad in column of files to the rear of the portion of the trench to be constructed by his squad. He usually halts his squad about 3 yards in rear of the cutting line and parallel to it. Work is started at the command: Commence work! The work should be divided into 2-hour tasks for each man. Weather conditions must at all times be taken in consideration. There should be one-sixth more men than theoretically required. Assuming men at 5-foot intervals and neglecting fractions the number of hours required to dig a trench is the section of trench in square feet divided by 5 for easy; 4 for medium, and 2½ for hard soil.

The table below gives the amount of work that can be accomplished in one hour by one man:

EXCAVATION—

In easy soil—

First hour....................cubic feet, 30
Second hour....................cubic feet, 25
Third hour....................cubic feet, 15
Thereafter continuous work....................cubic feet, 10

In hard soil, about half the above.
In loose earth, 60 cubic feet.
Filling sand bags, 20 bags (0.5 cubic foot each).

REVETMENT CONSTRUCTION (Material and tools on hand)—

Rough brush wood or plank....................sq. ft. per man, hour, 40

Brushwood hurdles, rough—

Making ....sq. ft. per man, hour, 15
Placing ....sq. ft. per man, hour, 30

Sand bags—

Filling ....sq. ft. per man, hour, 10
Placing ....sq. ft. per man, hour, 20

Sod—

Obtaining sod for....................sq. ft. per man, hour, 7
Placing ....sq. ft. per man, hour, 10

OBSTACLE CONSTRUCTION (Material and tools on hand)—

Abattis, wired (1 strong row)....................linear feet, 1.5

Wire entanglement—

High ....square feet, 27
Low ....square feet, 90

By working in two reliefs above figures can be increased by one-third.

CLEARING—

Thickets up to 1.5 inches diameter.......................square yards, 25
Light clearing of soft woods, trees to 12 in. in diameter.square yards, 25
Medium clearing...square yards, 15

Plate 13 shows in outline the general method of laying out and proceeding with the work.

OBSERVATION, TELEPHONE, WATER SUPPLY AND MAGAZINES.

Well concealed and well located observation stations are very necessary for a fortified position. These stations must afford the observer a maximum amount of cover and concealment, consistent with the performance of his duties.

A complete telephone system is necessary so as to afford ready

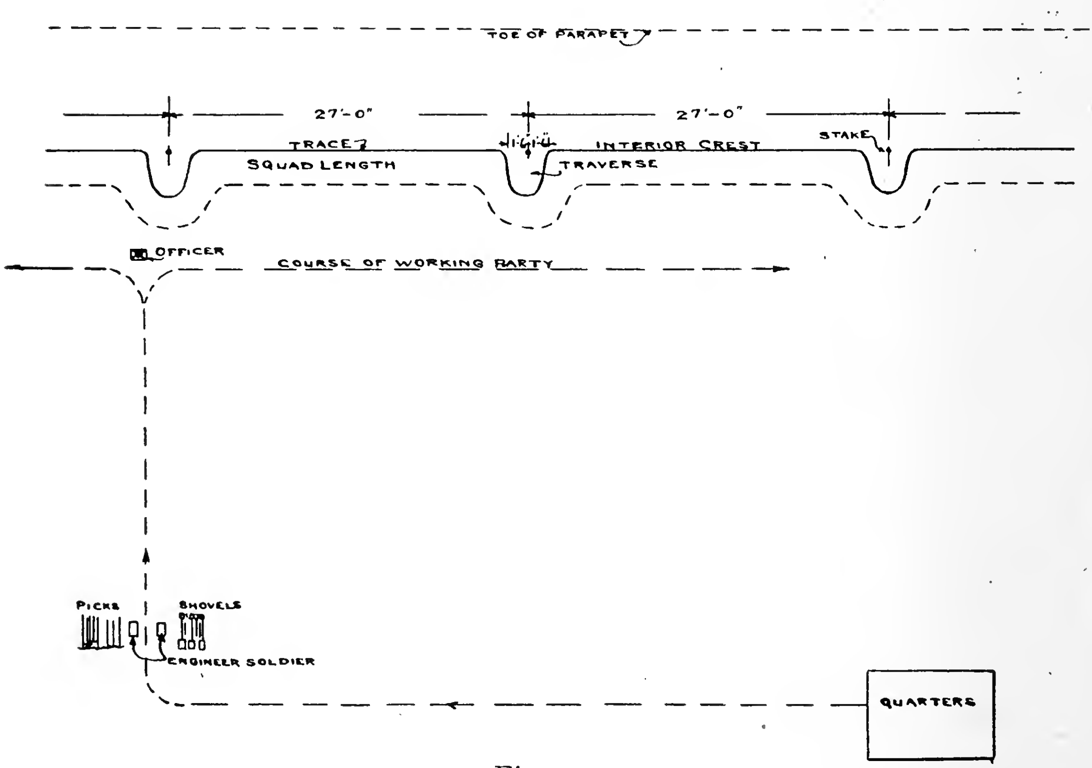


Fig. 13.

communication with all parts of the fortified position. With a complete telephone system, guns of the same batteries can be scattered over considerable area without the loss of fire control.

Good drinking water must be provided for the soldiers who occupy the trenches. Clean water is also a help for the "first aid" of the wounded. The arrangement to be made will depend on the local requirements and conditions.

Special magazines are not necessary. Recesses cut in front wall or cartridge boxes placed at convenient places will generally fulfil the requirements of ammunition storage.

A GERMAN FORTIFIED POSITION.

Major General Mayer proposes the following arrangement of a defensive position: As he considers that observation from aeroplanes may obviate the difficulty of locating the exact position of the defenders' shelter trenches, and he thinks a distinct difference should obtain in the defense against distant fire and against the close attack and assault. He constructs an advanced line of fire trenches for defense against the close attack and 100 meters behind this a second row of cover trenches, connected by approaches with the front line. Both are dug out on the front slope of a hill below the crest, the rear or cover trench being about 200 meters in front of the line of guns just behind the crest. He proposes to have no wire entanglements as obstacles because these would be easily seen and give away the position; but to have land-mines constructed 150 meters in front of the front fire-trenches. Machine gun sections should deliver frontal and oblique fire between the land-mines and the front line of fire-trenches to meet the close attack. Also machine guns for more distant frontal fire effect should be in position behind the line of cover-trenches. Machine guns in pairs should also be placed for flanking fire in or behind the shelter-trench for the close defense. This system cannot be spoken of as multiplying the defensive lines. It is a single line, if you consider that the second trench is simply a line of trenches arranged as a cover-trench for defense from distant fire. The designer pictures to himself the course of the action thus: The airmen have from their great height only been able to observe the ground very generally. The machine guns being easily masked, would remain unnoticed. The guns and rear line of machine guns open fire, say, at 1,500 meters, against the hostile infantry advancing cautiously to the attack. The line of defenders told off for distant fire would only open fire when the attackers reinforce strongly, then they use rapid fire. No shot is fired out of the front fire-trenches until the attackers come within 300 yards. Then the machine guns in the front line open fire and oblige the attackers to bring up field-guns to engage them. The men in the front shelter-trench open fire when the attackers are about 150 meters off and the mines have begun to act. This would be the moment for the counter-stroke by the reserve, which has been kept back concealed. The decisive line of defense is thus undiscovered until the decisive moment, which the defender utilizes to repulse the attack.

BRITISH TRENCHES.

The following remarks are extracted from Instructions in Field Training for the British Army. They are based upon the experience of the European War. They are especially applicable to fortifications which are to be occupied for a relatively long time and in relatively close proximity to similar works of the enemy. They are also of special interest as indications of the very great

power of modern weapons and the resulting necessity for concealment.

Trenches should be located so that they are not under observation by hostile artillery. Possible observing stations on ground occupied by the enemy should also be considered. This concealment is regarded as of greater importance than an extensive field of fire.

A field of fire of 100 yards will be sufficient if it cannot be extended without loss of concealment. Obstacles in front of the trenches must be carefully concealed, as otherwise they will assist the enemy to locate the trenches in rear.

A location for the trenches back of a slight rise or back of a second hedge with obstacles hidden or entangled in the hedge in front has been found to afford satisfactory concealment.

Modern artillery fire is practically continuous and the accuracy of ranging phenomenal. Accordingly, the target must be reduced to the smallest possible dimensions. This is best accomplished by making the trenches as narrow and as deep as possible with practically no parapet. Support trenches especially should be made deep. The support trenches should be about 40 yards in rear of and parallel to the fire trenches with ample communications to the latter. To these most of the men retire during a bombardment, leaving as few as possible in the fire trenches. Eighteen to twenty-four inches is sufficient width for a trench. As this does not permit of the free passage of men along the trench, communication is secured by means of a narrow trench about 15 yards in rear of the firing trench and connected to the latter at each traverse by a narrow passage of the same depth. (See Plate 14.)

The fire trenches should be of the recessed traversed type whenever time permits, traverses about 5 feet wide at the base and 35 feet center to center. (See Plate 15.)

Surplus earth from the trench excavation should be spread or sodded, depending on the nature of the soil.

A bank of earth as a parados should be placed behind and close to the trenches for protection against the back blast of high explosive shells, provided this can be done without rendering the trenches conspicuous. These parados should be sodded or otherwise concealed in the same manner as the parapet. Dummy parapets may be constructed with surplus earth.

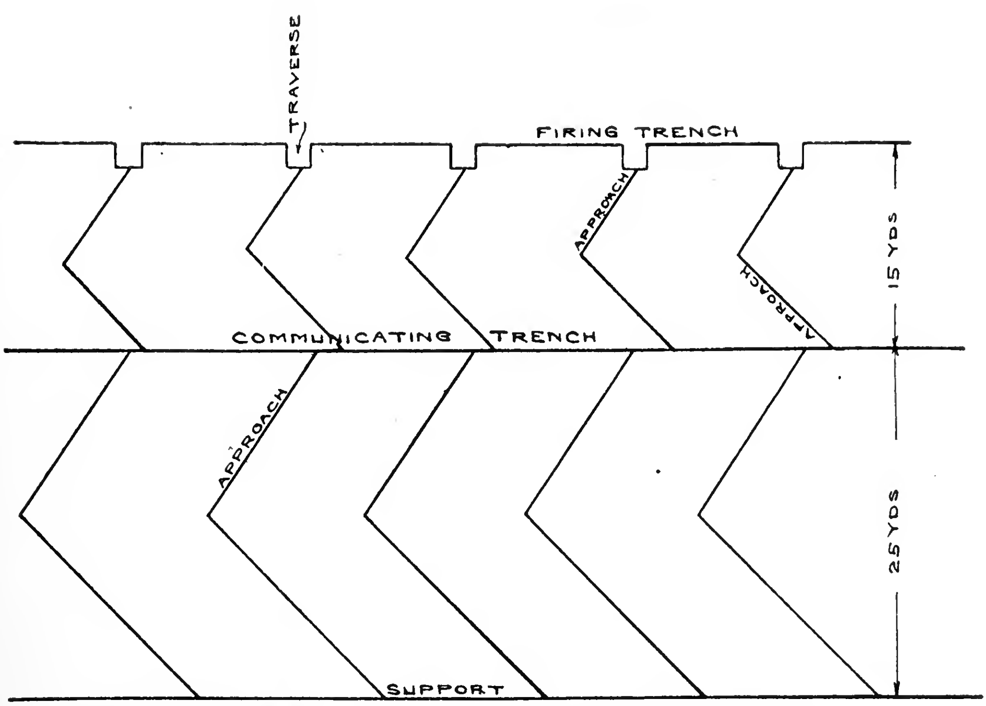
Recesses under the parapet must be ceiled. If planking or other similar material is available time and trouble may be saved by laying the ceiling for the recesses on the ground at the front of the trench, with a good bearing at the ends, and then excavating the recess and throwing the earth on top of the ceiling to form the inner part of the parapet. The recesses serve to protect their occupants from shrapnel fire.

Elbow rests should be omitted or made very narrow. Most of the men will prefer to make their own niches for the forearm. A

device to ensure proper aiming in the absence of lights during a night attack is desirable.

Head cover and overhead cover are usually impracticable, except at points to be used as observing stations. They restrict the use of the rifle and bayonet. Where head cover can be constructed to advantage a continuous loophole is the best form.

The arrangement of trenches should be such as to develop as much frontal fire as possible. Attacks by the enemy usually occur at frequent intervals at night along the whole line. Under such conditions adjacent sections of the line can give but little support to each other by crossing fire. As cross and flanking fire is not to be relied upon, straight trenches are preferred.



GENERAL PLAN OF MODERN BRITISH TRENCHES

Fig. 14.

Dressing stations and latrine may be provided in recesses in the support trenches.

Drainage should be considered in laying out the trenches. When practicable they should be drained to a low point in the locality. When this is not practicable, sump holes must be provided in the trenches, to be pumped or baled out.

Machine gun emplacement should be on the flanks of a section and as well concealed as possible. They should not be unmasked too soon, as this exposes them to premature destruction by the hostile artillery.

Cover required for the reserves will depend upon their distance in rear of the firing line and the enemy's ability to search with fire

the ground in which the reserves are stationed. The possibility of observation by aerial reconnoissance must always be considered.

Obstacles must be provided to check the enemy's attempts to rush the trenches. Barbed wire is the most effective obstacle, especially if well concealed. The advantage of concealment, in addition to preventing the use of the obstacles as range marks for the trenches in rear, is that working parties are enabled to repair each night any damage to the obstacles. This repair work must frequently be carried out not over 100 yards and occasionally not over 50 yards from the enemy's trenches. High wire entanglements involving the use of posts extending 3 feet 6 inches or 4 feet above the ground are impracticable owing to the difficulty of concealment and of repair. The driving of such posts is out of the question when

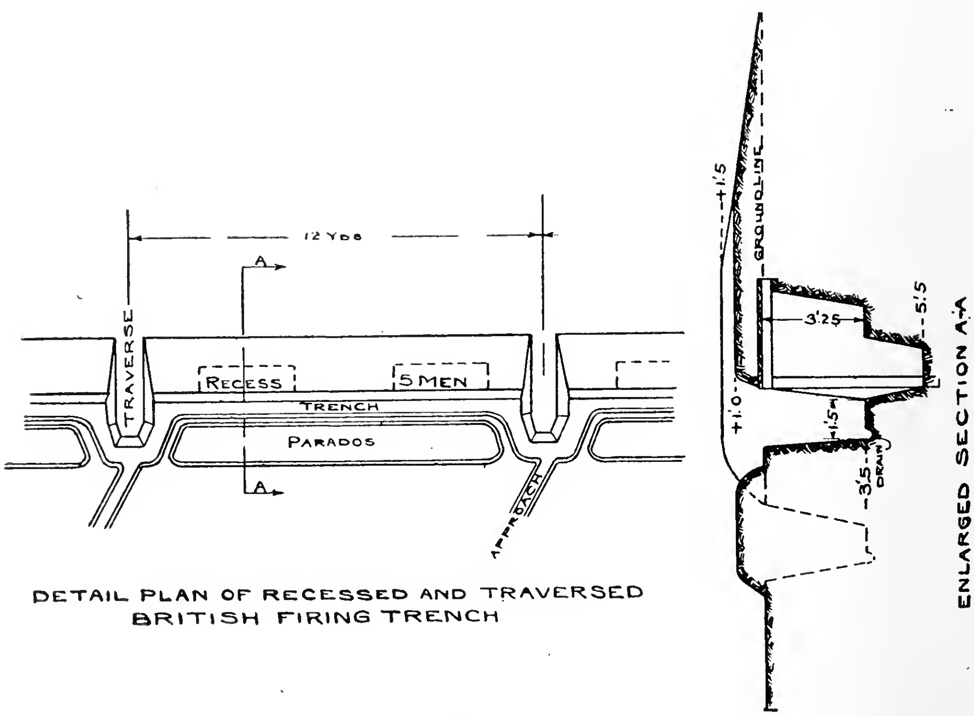


Fig. 15.

hostile trenches are in close proximity. Various substitutes for these posts may be employed, such as tripods, constructed of the limbs of trees lashed together, carried out and set in front of the firing line at night, at intervals of about 15 feet. The tripods are anchored to the ground and barbed wire laced between them. Any light, strong, portable support for barbed wire entanglements is acceptable.

Flare lights shielded on the side of the defender may be employed.

If the flank of a line is refused, the trenches should be echeloned to the rear. Otherwise the trenches on the flank will be subject to enfilade fire, especially by heavy artillery at long ranges.

The following observations of the aeronauts will be of assistance to those engaged in the construction of field fortifications:

1. A long continuous line of trenches is more visible than groups of trenches.
2. Straight trenches are conspicuous.
3. Trenches across plowed fields are easily distinguished.
4. Straw spread in the bottom of trenches renders them conspicuous.
5. Trenches against hedges cannot be distinguishable.
6. It is difficult to tell whether trenches or gun emplacements are occupied.
7. Tracks to emplacements are easily distinguished.
8. Trenches should be covered with brush to hide deep shadows at bottom.
9. The operations on the European battle fields closely resemble the methods which have hitherto been considered characteristic of sieges.

Sir John French says: "In war as it is today, between civilized nations armed to the teeth with the present deadly rifle and machine gun, heavy casualties are absolutely unavoidable. For the slightest undue exposure the heaviest toll is exacted. The power of defense conferred by modern weapons is the main cause for the long duration of the battles of the present day, and it is this fact which mainly accounts for such loss and waste of life. Both one and the other can, however, be shortened and lessened if attacks can be supported by a most efficient and powerful force of artillery available; but an almost unlimited supply of ammunition is necessary, and a most liberal discretionary power as to its use must be given to artillery commanders. I am confident that this is the only means by which great results can be obtained with a minimum of loss."

PERMANENT FORTIFICATION.

The ease with which the Germans successfully captured Liége, Namur, Antwerp, and the camp retranches of Maubeuge, Lille, Laon-La Fere and Rheims, all very strong positions on paper, has proved rather damaging to the prestige of permanent fortifications. Yet there is no case for a wholesale condemnation of forts when circumstances are carefully examined. Both Belgian and French fortresses were sadly out of date in armament as well as in defensive organization, and were crushed at long range by an artillery of superior caliber (280, 305 and 420 millimeters—11.032, 12.017 and 15.548 inches) to which they could make no effective reply. To the admirably handled German heavy ordnance that fired with incredible accuracy at ranges of ten to fourteen kilometers, the French fortress artillery could only oppose, together with obstacle mortars and insufficient field guns, weapons of 155 millimeters (6.107 inches) with a range of little over 8,000 yards.

No attempt was made to defend Lille, Laon and Rheims, totally out of date and not thought to be worth the huge garrisons which

they would have absorbed. Maubeuge alone offered a stout resistance, though perhaps not so long as could have been expected from its new (but under-gunned) forts and from its garrison of 30,000 men, including nine infantry regiments and a few artillery battalions, mostly reservists. That place-forte, besides having no long range cannon, was filled by tens of thousands of helpless Belgian refugees, mostly women and children, which constituted a source of weakness. After a ceaseless night and day bombardment, lasting from August 23 to September 7, in the course of which the garrison did its duty, attacking continuously and inflicting over 20,000 casualties on the enemy (so much was admitted by German officers), the governor, Gen. Fournier, surrendered a town on fire, full of dead and wounded, the forts of which were reduced to heaps of ruins. Only a few thousand men of the garrison succeeded in breaking through the lines of the besiegers.

It is estimated that Maubeuge rendered considerable service in delaying for two weeks the advance of an important portion of the hostile artillery and in preventing the enemy using the most direct railway line from Liege to Paris. The same is true also of the obsolete fortress of Longwy, where 3,000 Frenchmen stopped for twenty-one days part of the Kronprinz's army, winning war honors from the victor, and of the old (1874) fort of Troyon, with a garrison of 470 men, which the enemy was confident of reducing in a few hours, but which resisted an intense bombardment of five days, repulsed three brave attacks of German infantry, and cost nearly 2,000 casualties to the besiegers.

But, of course, reliable information as to the value of fortifications can only be derived from a study of the way modern fortresses have stood the test of war. Now, the camps retranches of Verdun, Toul, Epinal and Belfort are the only ones that deserve at all to be called modern, having been the object of ceaseless improvements in recent years, though at the beginning of the war they were not quite up to date in armament, not having received the long range naval guns that now arm them. And it is a fact that they have up to the present defied the whole might of heavy German guns and the repeated and well-led attacks of the masses of German infantry, especially Verdun, which is yet partly encircled, though at very long distance—over 20,000 yards.

From reliable sources we further learn that the excellent resistance offered by the Verdun fortifications is also due to the fact that many of the large guns were removed from their permanent emplacements and were then placed in concealed positions from which they could be readily moved in case the enemy discovered the position.

Several semi-permanent emplacements are provided for each gun.

The small circular fort, with its batteries, powder magazines and garrison quarters crowded over a limited area is a thing of the past. The permanent fortification with mobile and concealed bat-

teries distributed over a large area, and well placed and concealed infantry intrenchment is and will be of great value. This is the opinion of some of our army engineers and some of the foreign military experts.

The author herewith sets forth the requirements and conditions which he believes are necessary to withstand successfully the attack of the present high power weapons:

1. Superiority of range and armanent.
2. Concealment and mobility of armament.
3. Wide area of operation.
4. A cleared area around site of fort.

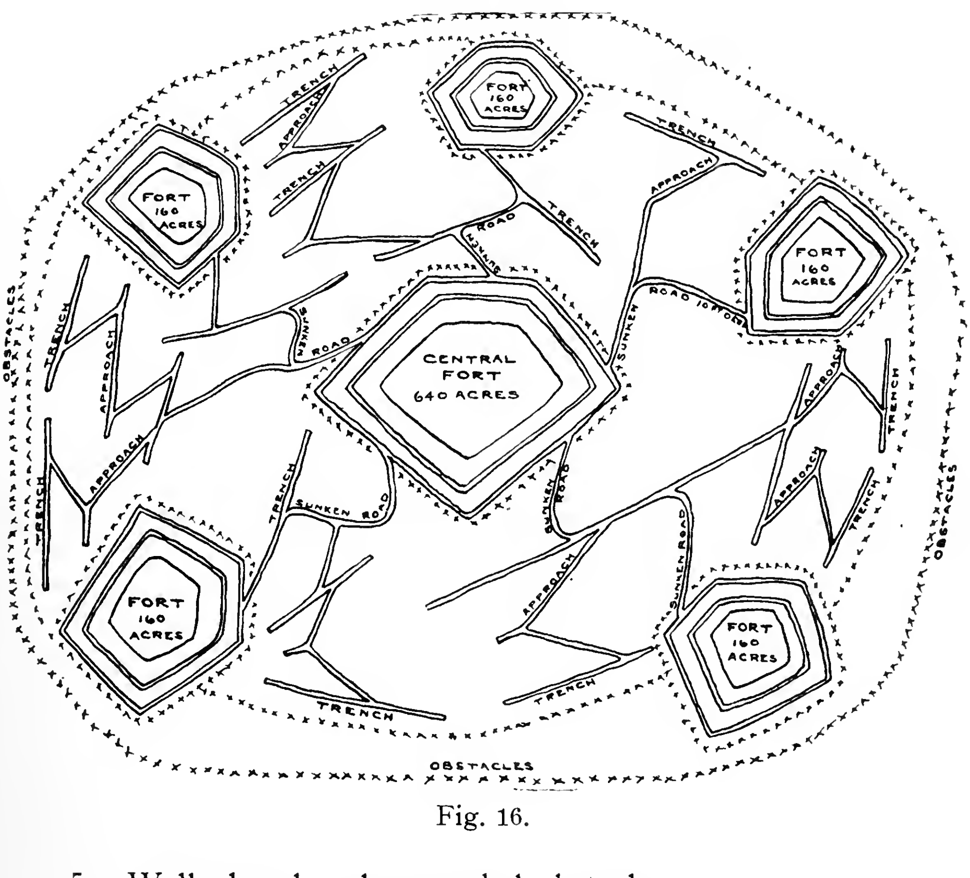


Fig. 16.

5. Well placed and concealed obstacles.
6. New type armored turrets.
7. Dummy turrets.
8. Concealed infantry trenches.
9. Centrally located magazines.
10. Cover for garrison.
11. Covered and concealed communications between the different parts of the fort.
12. A complete telephone and wireless system.
13. A complete lighting system.
14. Ample water supply.

Plates 16 and 17 will give a general idea of the author's plan

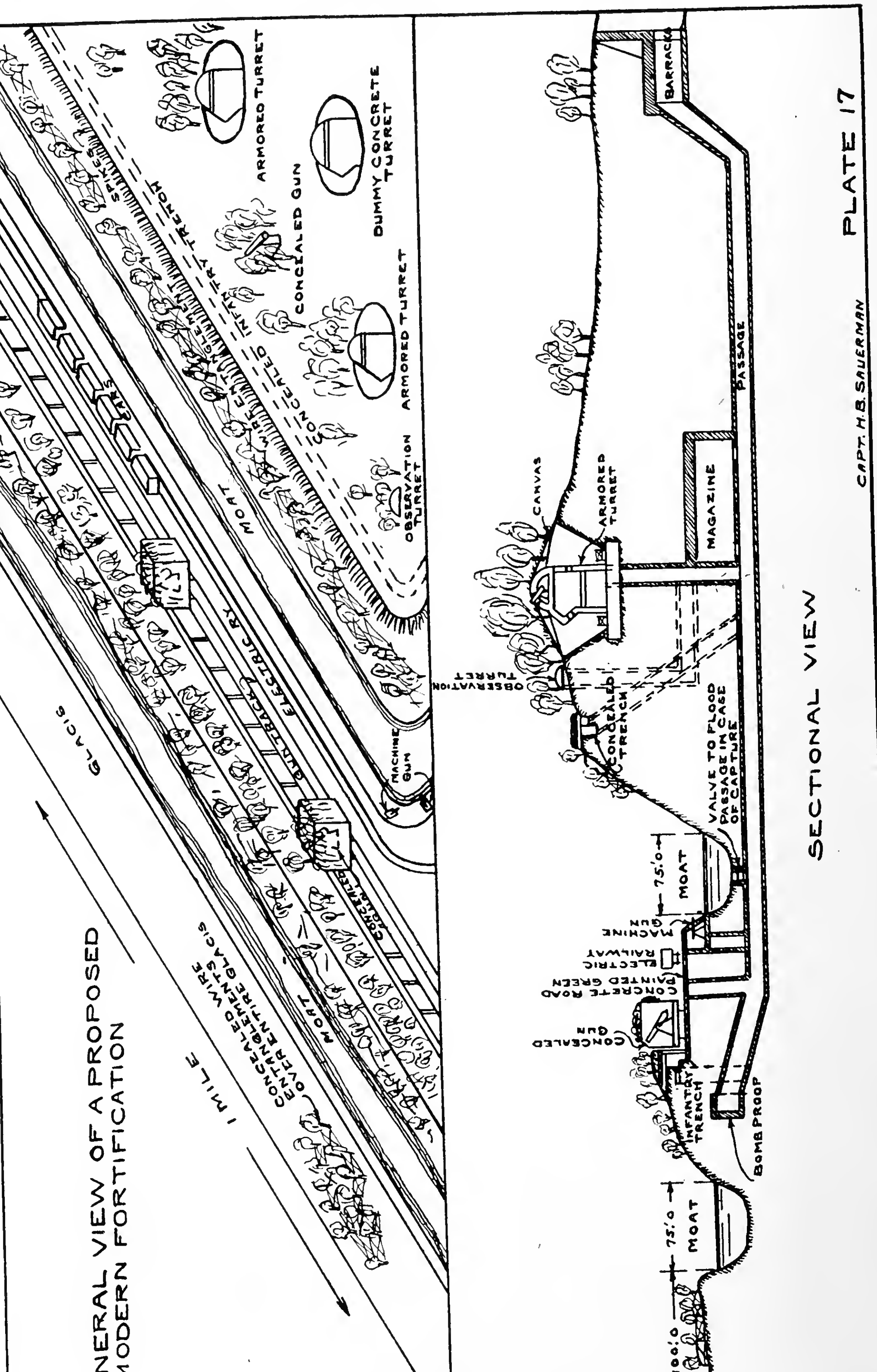

GENERAL VIEW OF A PROPOSED MODERN FORTIFICATION
1 MILE
GLACIS
MOAT
CONCEALED WIRE ENTANGLEMENT
ELECTRIC RY.
CARS
MACHINE GUN
SPIKES
INFANTRY TRENCH
ARMORED TURRET
CONCEALED GUN
DUMMY CONCRETE TURRET
OBSERVATION TURRET
SECTIONAL VIEW
PLATE 17
CAPT. H.B. SAUERMAN
BARRACKS
PASSAGE
MAGAZINE
CANVAS
ARMORED TURRET
OBSERVATION TURRET
CONCEALED TRENCH
VALVE TO FLOOD PASSAGE IN CASE OF CAPTURE
75'0
MOAT
MACHINE GUN
ELECTRIC RAILWAY
CONCRETE ROAD PAINTED GREEN
CONCEALED GUN
INFANTRY TRENCH
BOMB PROOF
75'0
MOAT
100'0

Fig. 17.

of a modern permanent fortification. As to the thickness of cover, lighting system and other exact data and details we must await the further developments of this present war.

SEA-COAST FORTIFICATION.

General Bernard, in one of his reports, outlined the use and purpose of seacoast fortifications as follows:

"Seacoast fortifications must close all important harbors against an enemy and secure them to our commercial and military marine.

"Second, must deprive the enemy of all strong positions, where, protected by naval superiority, he might fix permanent quarters on our territory, maintain himself during the war and keep the whole frontier or coast in perpetual alarm.

"Third, must cover the great cities from attack.

"Fourth, must prevent, as far as practicable, the great avenues of interior navigation from being blockaded at their entrances into the ocean.

"Fifth, must cover the coastwise and interior navigation by closing the harbors and the several inlets from the sea which intersect the lines of communication, and thereby further aid the navy in protecting the navigation of the country.

"Sixth, they must protect the great naval establishments."

Wars of recent years, as well as the present European War, have demonstrated that it is practically impossible to reduce seacoast fortification, if properly defended, by ships' fire, and, when fortified posts have fallen, such a result has been secured by land operation assisted by a blockade. The proper land defense in connection with coast defense is therefore an absolute necessity.

An effective system of coast defense must consist of land batteries, with their protecting guns and searchlights, submarine mines, torpedoes, torpedo and submarine boats, floating defenses, barricades, dams and proper land defenses.

To prevent distant bombardment by a fleet, and also to prevent the forcing of a passage or a running past the defenses, high-power guns are required for disabling or silencing battleships and cruisers at long ranges, and in addition to the mines smaller guns of the rapid-fire type are needed for similar purposes and to repel torpedo-boat attacks at the closer ranges.

Seacoast fortifications are best protected from the attack from the land side by mobile troops well entrenched and supported by sufficient mobile artillery. The heavy guns and mortars should also be designed so that they can be turned and used in the land defense.

Mines are and should be considered as obstacles and in order to accomplish their object must succeed in holding the enemy in the zone of greatest effective fire. They must allow safe passage of the vessels of the defense but must be instantly dangerous to the enemy's ships.

The United States coast defense is provided with 8-inch, 10-inch, 12-inch and 16-inch caliber guns for heavy armament. The mortars

are mostly of 12-inch caliber. The rapid-fire armament consists of 6-pounders and 15-pounders and 5-inch and 6-inch caliber guns.

The long range guns are usually placed at a height of 165 to 250 feet above sea-level.

The mortars are usually placed at a height of 260 to 300 feet above sea-level.

The lighter and rapid fire guns are usually placed at height of about 60 feet above sea-level.

Three systems of range finding are now in use:

1. The horizontal base system with a horizontal base along shore and which has an observation station at each end of this base. The target is located by the intersection of the lines of sight from the two stations.

2. The vertical base system with the vertical height of instrument above mean low water as the vertical base. The distance to

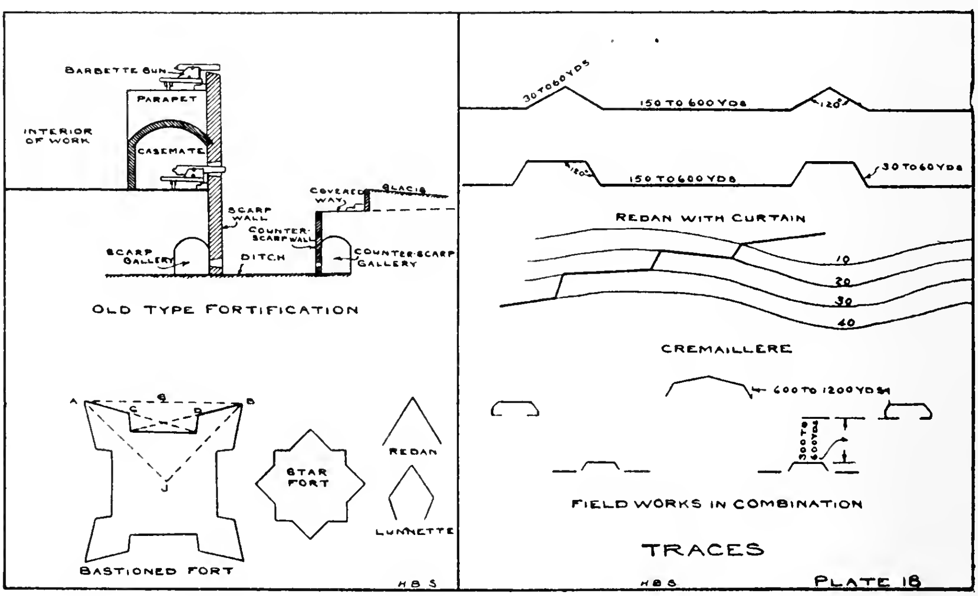


Fig. 18.

the target is read off the instrument in yards directly when the horizontal cross-wires of the telescope is directed on the water line of the target. The azimuth is obtained on the graduated horizontal circle.

3. The third system is the coincidence range-finding system, which requires a single station equipped with a coincidence range finder. This range finder is equipped with an azimuth reading device.

For protection and cover, some of our sea-coast fortifications are provided with 15 feet of concrete and 45 feet of sand for walls exposed to horizontal fire and 10 feet of concrete where exposed to vertical fire.

Mobility and concealment of armament should receive special

attention in modern fortification. Some of the large European fortresses are equipped with heavy mobile armament and which is protected with steel cupolas.

Conditions for good mine locations are shallow water and gentle current. A depth of about 100 feet and a current of about 7 feet per second are the respective limits.

Excessive tide ranges (over 10 feet) require a double system of mines; one in front for low water and another in rear for high water. The mines should be laid checker-board fashion with intervals not greater than 60 feet.

Electric contact mines are generally used in coast-defense with their cables connected to the firing station on shore. All mine fields

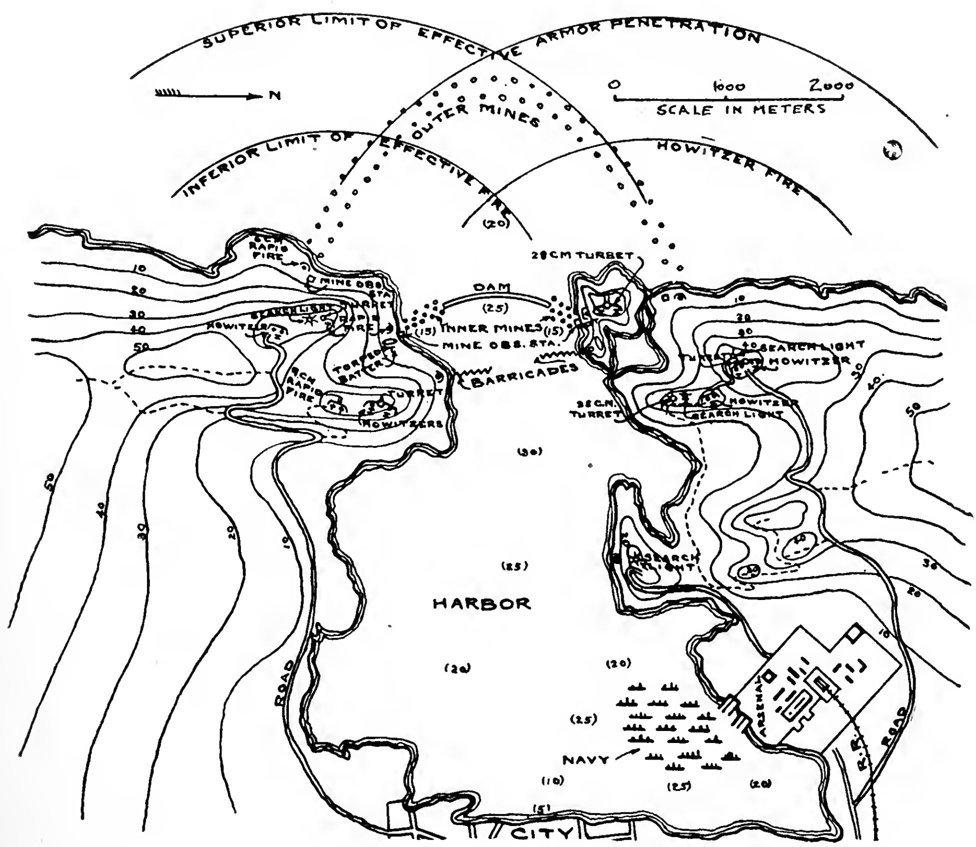


Fig. 19.

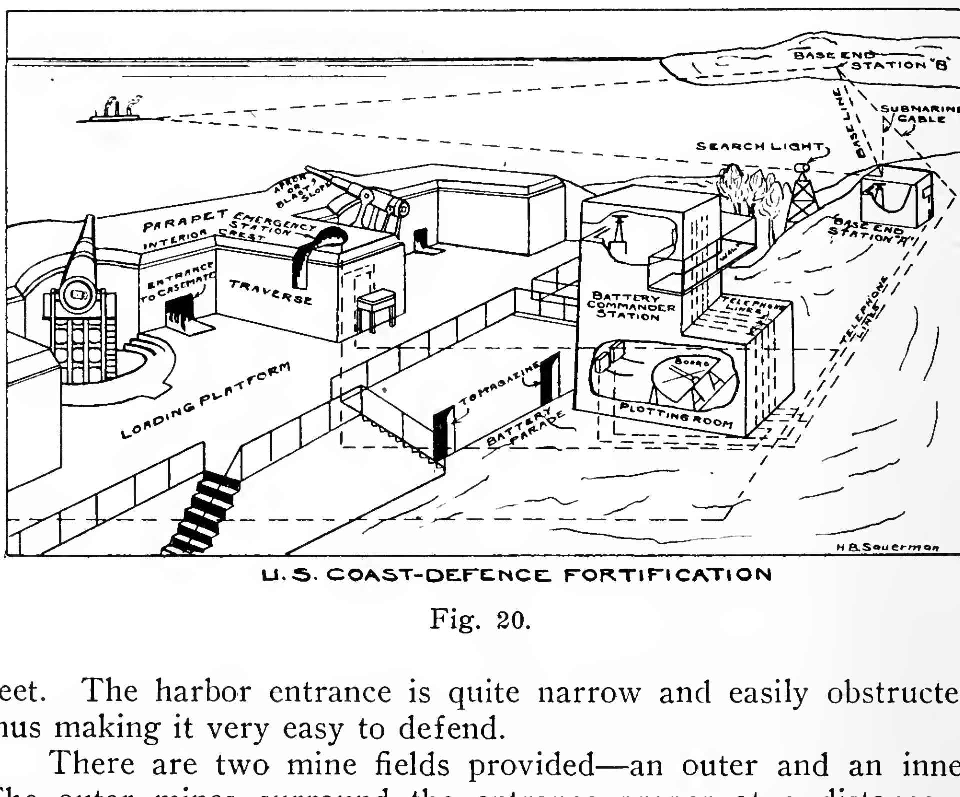
should be protected by rapid fire guns usually placed on the flanks of the mine field.

Two examples of effective sea-coast fortification of the present European War are the fortifications of the Dardanelles and the fortifications of the Island of Helgoland. The fortifications of the Dardanelles have successfully withstood the combined naval and land attack and have inflicted severe losses on the enemy, both in ships and men. The fortification of the Island of Helgoland may be classed as the greatest military engineering work of this age. A

small barren and rock-strewn island has been transformed into a formidable defensive work and so well has the work been planned that Germany's entire navy finds absolute protection behind this island, against the attack of the greatest navy that has ever cruised the waters of the world.

To illustrate a modern fortified harbor, the system of the Austrian, Colonel Mielichhofer, is reproduced in Plate 19.

The surrounding country of this harbor rises to 60 meters above sea-level, which permits of easy fortification. The inner harbor allows of the location of arsenals and magazines which are entirely covered by the heights, so that these works are not only protected from bombardment by distance, but also by their position. The inner harbor is of sufficient area to accommodate the entire



U. S. COAST-DEFENCE FORTIFICATION

Fig. 20.

fleet. The harbor entrance is quite narrow and easily obstructed, thus making it very easy to defend.

There are two mine fields provided—an outer and an inner. The outer mines surround the entrance proper at a distance of about 2,000 yards and this mine zone is located in the most effective zone of fire of the heavy coast guns. The mines are located and arranged in a double row. The mines nearest to shore are judgment mines, which permit the vessels of the defense to pass over them uninjured, while the others are contact mines.

The inner obstructions consist of a submarine dam at the center of the entrance with passages at each end which are closed by judgment mines. In rear of these mines barricades are placed.

The mine fields and barricades are flanked by rapid fire batteries

and shore torpedo batteries. The field of fire is illuminated by means of searchlights.

Plate 20 shows a typical sea-coast fortification in detail.

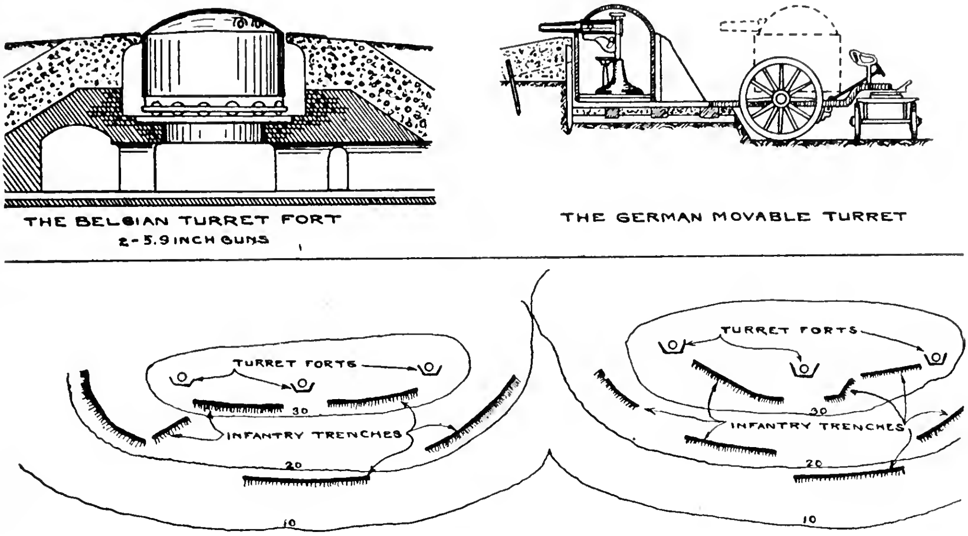


Fig. 21.

Plate No. 21 shows a Belgian steel turret fort; also a German portable turret. These steel turrets are usually placed in combination with trenches as outlined in plan on this plate.

DISCUSSION.

Horace S. Baker, M. W. S. E.: I feel that this paper by Captain Sauerman is a remarkably thorough treatise on the subject of fortifications. A number of regular army officers have examined it and have commended it highly. Both Lieut. Guilfoil and myself have been pupils under Captain Sauerman. In fact, we began with a pick and shovel and worked in the trenches, so you might say we began at the bottom. The principles that he outlines are the ones we all have to follow. Tactics are the basis of all this work. None of us have very much trouble with the ordinary engineering work that we are used to, but the big thing in fortification work as we see it, is placing them in the right place. It is possible to waste a great deal of labor and time in constructing fortifications, which are found to be of no use at all. Judgment and experience and skill must be obtained in advance, so that fortifications can be built where they will be most useful if they are needed.

I want to speak again of the value of this paper because I believe that it is a remarkably thorough and practical treatise on the whole art of fortification.

Ernest McCullough, M. W. S. E.: My present service is with the field artillery, the branch of the service which is charged with

the attacking of infantry and cavalry while advancing. We must do what we can to prevent them entrenching, therefore, it is us the engineers must protect themselves against. After the advancing enemy is intrenched, our guns are of little service and heavier guns must be brought up. The field artillery is divided in some armies into light, heavy and horse. The difference between the light and horse artillery is that in the latter, every man is mounted in order that the batteries may be as mobile as cavalry. Light artillery and horse artillery use, in the United States Army, the three inch field piece. The 75-mm. field piece of the French is 2.95 inches and the 77-mm. gun of the Germans and Austrians is 3.08 inches bore. The British field piece has a three inch bore. In fact, practically every country having an army worth considering, uses a light field piece of 75-mm. bore. This is governed by the fact that no more than six horses can be conveniently used to haul guns around with sufficient mobility to accompany infantry and cavalry. This fixes the weight of the piece and caisson.

The weight having been fixed the amount of ammunition to carry is subtracted, together with the weight of the wheels, axles, etc., and the remainder of the weight is all that can be permitted for the gun. The size is thus practically standardized because the work of the artillery is the same in all armies. When the enemy intrenches the three inch gun is withdrawn and the three-point-eight inch howitzer, with a field piece of the same bore, are used against the trenches. When the trenches assume a more permanent form there will be brought up the four-point-seven howitzer and the four-point-seven field piece later, to be followed by the six inch guns. I believe the United States has less than 700 three inch guns of which about two-thirds are in the army and national guard, the rest being packed away in grease and oil at the arsenals. Great Britain at the commencement of the present world war had 3,600 field pieces and was the poorest off of all the European countries in that respect. The United States has perhaps a dozen field pieces larger than the three inch, for experimental purposes.

Formerly, and it was not so many years ago, the line officers were not expected to know much about fortifications. This was left to the engineers, who were used principally as teachers. Engineer troops were put to work on the fortifications. Today every officer in each branch of the service is suppposed to know as much about field fortifications as is presented in the paper by Captain Sauerman. Formerly the engineers did the signalling but today, and in future wars, the engineer's work is almost solely that of keeping open lines of communication and his work on fortifications is merely in a directing sense. The engineer troops will keep up the highways and railways and restore bridges. They will also destroy roads, railways and bridges in the rear of retreating troops for protection. Today every commissioned and non-commissioned officer is taught how to make road maps, position sketches, and, in the artillery, panoramic sketches, so the engineer troops so far

as map making is concerned will be used before the war begins to make and collect maps and after the war begins they will be the clearing house department for information concerning a country. The hasty maps will be made by whoever needs them and the engineers will make the finished maps and correct errors in the maps made by other troops.

The work of listening to lectures on military work and reading books on military subjects is well enough in its way. But it is not enough. New graduates of engineering schools are shocked to find that it is hard to get employment without a showing of good experience. All the study in the world will not make a man fit for military service unless he knows something about practical military work. That is, it is not enough to know how to do a thing, but one must be able to do it. The ability to do comes by doing, and if any one here seriously contemplates volunteering in time of war he should join a National Guard organization and drill. The drill with arms teaches team work and respect for authority. The drill in making maps, making bridges, throwing up entrenchments and work of a similar nature introduces the engineer to the difference between his work as a military engineer and his work in time of peace as a civil engineer. If this country is called on suddenly to send into the field several brigades of engineer troops, it will be found that they will be long on brain and short on muscle and very, very green. The work of the military engineer and of the average engineer in civil life is so bafflingly similar that a great many engineers think we would have no trouble in getting all the first class engineer troops an army will need.

But it is not true. You cannot take men from civil life and throw them suddenly into military work and have them make good from the first jump. In civil life, some attention must be paid to doing the work in accordance with good engineering practice, at a minimum cost and within a reasonable time. In the army the cost is not considered for men enough to do the work are drafted from troops not fighting. The material is picked up wherever it may be had. No design is prepared, but an attempt is made to adhere as closely as material and circumstances permit, to approved methods and forms given in the military engineering hand books. Speed is the first consideration regardless of expense. It may be impossible to erect a bridge with materials at hand which will be strong enough to carry artillery but it will carry infantry and the artillery must find another crossing or merely support the rest of the troops from the near bank. It is speed and efficiency with a view to accomplishing definite results which spur on military engineers. These things cannot be learned by reading or listening to lectures. They can be learned only by doing them over and over again. Men must be trained to think and act instinctively in the right way. There is little time given for thinking, and he who stops to think is lost. Constant drill is needed to develop in

men the instinct born in the cat of lighting on the feet no matter how many times it may be turned over in the air.

I was in company with some engineers a short time ago, and they spoke rather slightingly of the methods of military men and of the long and severe training such men thought was necessary. They said that when a war comes the highly educated citizens in the United States will surprise the military men. They will do nothing of the sort. The military men know just what to expect of raw volunteers from civil life. The soldier has been learning his business, the oldest in existence, even older than that of the farmer or stock raiser, for many centuries and is readier than men in civil life to cast aside precedent and adopt new ideas. He has, of course, some "Custom of the Service," which are in spots antiquated and not entirely in place in a democracy, but these things are no worse than common social usage, which we all decry, but no one has the courage to disregard. It has been well said that war to the soldier is a trade, to the officer in the field it is an art and to the supreme commander it is a science. It is given only to the men who have been educated in the regular way and who have studied and read for a lifetime to be scientific practitioners of war, so only the highest officers in the regular army will have that cold-blooded pleasure. They must all learn the trade and those who show proficiency will get higher, to where as officers they can practice the art of war. Now, if any of you have aspirations to become commissioned officers in time of war, I may warn you that you will hardly get the chance. In the next war the regular army will go out first. The national guard will probably suffer by having its best enlisted men sent to fill the ranks of the regular army to bring it to war strength. This will insure that every man in the regular army has had some training. The first volunteers will be sent in to fill up the ranks of the National Guard to war strength. When, and not until this is done, will regiments of volunteers be raised. For these regiments, captains and lieutenants of the regular army will be detailed to serve as field officers and good non-commissioned officers from the regular army and national guard will be detailed to serve as captains and lieutenants. The days of the politically appointed officer have gone by forever, let us hope.

In Great Britain schools were started for the training of officers and it was necessary for a man to come of a family that was known in order to get a commission. It was the exception to promote men from the ranks because Lord Kitchener was against rankers, even though they were born gentlemen. In the United States, of course, there is no prejudice in favor of the rich and well born, rather the reverse, so our special training schools for officers in time of war will be the camp and the battle field. In time of peace it is necessary to have as much special training as possible. This can be accomplished nicely by a man following a prescribed reading and study course and by

attending drill regularly. Then, he should take examinations from time to time, and by and by he will attain enough merit to be carried on the records of the War Department as a reserve officer.

I have had an idea in mind for a long time to provide for the men whose business takes them away from the city frequently or who for other perfectly good reasons cannot attend drill regularly. It is that in every military organization there be permitted a certain per cent of such men who can drill with the organization, yet take no oaths and be under no obligations. They can own their uniforms and equipment and attend drill when possible, a limit being fixed of a minimum number of drills per year. They should be required to attend non-com school a certain number of times also and be required to take certain examinations annually. If this plan can be worked out it should serve admirably the purpose of bringing to the notice of the war department the names of hundreds of well educated men with some military experience. These men should be required to attend camp each year for not less than two weeks.

President Grant: I would endorse one of the things that Mr. McCullough has said: Things that have to be done should be learned by doing them. I don't think a correspondence course will teach a man to shoot straight.

Fred J. Postel, M. W. S. E.: I have nothing to add to the paper, but I would point out that a paper such as we heard this evening opens up a wide field for serious thought, especially to a man who imagines you can raise an army of a million men over night.

It was my good fortune to serve for a little over four months in the Engineer Corps during the Spanish-American war in 1898. The instruction we received during those first four months did not extend to the problems discussed by Capt. Sauerman in his paper this evening. This, naturally, suggests the question "If, after war is declared, it takes more than four months to train volunteer engineers (recruited to a large extent from among engineering students of our leading colleges) up to a point where they are ready to undertake the solution of problems such as those discussed tonight, how long will it take to train them to a point where they are really ready for service at the front?" Last, but not least, what would the enemy be doing to us in the meantime? In my opinion, therefore, aside from the value of the paper as a technical military treatise, it is one of the strongest arguments for preparedness that I have seen.

D. A. Tomlinson, JUN. W. S. E.: There are one or two things about this paper tonight that struck me very forcibly. One is this: In the last year and a half the Western Society has had several evenings devoted to military tactics. We have had Lieut.-Col. Judson, we had Lieut. Baker last fall with a highly interesting talk on the engineering work down in Virginia, where the militia engineers went last summer for two weeks' training, and now

tonight Captain Sauerman gives this very able paper on fortification, and it is a splendid tribute to the interest of engineers in national defense, that there has been such a good attendance on each of these occasions.

To my mind the most important thing before the country today is this subject of national defense and I say that knowing that some in this audience well know that two years ago I was an ardent pacifist and thought that all expenditures for battleships were an economic waste. I still think so, but I think that if we do not make these expenditures, this economic waste, we are going to be in the position that Belgium and other countries across the water are.

It seems as if it was taking Congress a long time to provide any adequate system of national defense, and it will take a longer time to put any system in action. The first of the month I was in St. Augustine and went to an old fort called Fort Marian that was started in 1565, but not completed until 1656, 91 years later. Evidently military development was even slower then than now. I doubt if it is going to take this country 91 years to get into a state of military preparedness.

Compared with the fortifications that Captain Sauerman has illustrated in his paper, Fort Marian is a very small affair. It is possibly 300 feet square; the walls are very thick, from 28 to 40 feet, and are built of "Coquina," a soft stone which is a composition of seashells. It is so soft that you can almost stick your fingers into it, but 200 years ago the cannon balls did not explode as they do today, and would only penetrate a few feet, if the walls were soft, without shattering them, whereas if the walls were constructed of harder stone the impact of the cannon balls would eventually destroy the fort. Around the fort you can still see holes that were made by cannon balls. The fort incidentally would be an excellent target for any modern gun, because it is visible for a long distance and its guns could not be moved.

I understand, incidentally, in connection with that fort, that it was first built by the Spanish and that an old Spanish king once climbed to the highest point in his tower and looked out across the Atlantic Ocean. One of his retainers asked him what he was looking for. "Well," he said, "I'm looking for Fort Marian." "Why, you can't see it this far, your Majesty." And the king replied: "Well, it has cost me enough so that it ought to be visible around the world."

E. N. Layfield, M. W. S. E.: I am not able to qualify as an expert on fortifications, but I had something to do with getting Captain Sauerman to present this paper, and I just want to say that I think we perhaps are entertaining an angel unawares. I think that Captain Sauerman is a much greater authority on this matter than any of us realize and I believe that this paper of his will be one of the standard works on the subject. He was extremely modest during the negotiations I had with him, but I finally suc-

ceeded in getting him to admit the fact that some high military officers had seen parts of this paper, and I still later succeeded in getting him to show me some of the letters that they had written. I will also add that within the last few days I received a request from the superintendent of the West Point Military Academy, asking me to furnish him with some copies of it, which I very gladly did.

V. R. Walling, M. W. S. E.: I can only express my appreciation of the very excellent paper that was given and to say that it startled me to find there was such a depth to the subject that I think the ordinary layman has no conception of. The thing that has been most pleasing to me is the spirit in which the members and friends of the members have taken to this preparedness proposition. I can remember about a year ago, when there was something along this same line introduced in this meeting by Lieut. Baker, in which he, and I believe the most prominent members of the National Guard, signed a paper that the matter of preparedness be brought up in the Western Society, and being seated among the members that evening, I heard considerable criticism of his remarks. And he had at that time a very small following. It is very evident tonight from the number that are here and the interest with which they have listened to the discussion, that everybody is becoming alive to the situation and I think that one thing we all should do, is to endeavor to stir the body at Washington, who are really the ones who have the power to get things started, by putting before them, as their constituents, the very urgent need of prompt legislation to bring our army and navy up to the requirements of a first class power, such as the United States, for adequate defense. What these requirements are, to be left to the judgment of the Army and Naval Board who are this country's experts in such matters.

Captain H. B. Sauerman: I can only add that the object of this short paper is to impress upon the civil engineer and militia officer the importance of fortification, to show him how to analyze some of the problems and situations, to give him some of the main underlying principles of fortification and to create a desire for further study. And, further, to show the practical application of fortification in modern war. If I have succeeded, or partly succeeded in doing that, I am certainly well satisfied. The work of fortification requires a study of tactics. As Lieut. Guilfoil read that a lot of work can well be done by civil engineers, fortification will require tactics, and as Mr. McCullough said, to get the knowledge of tactics you will have to learn the trade.

IN MEMORIAM

Frank Hayward Pond, M. W. S. E.

Died April 12, 1916.

Frank Hayward Pond died at his home in Chicago on April 12, 1916, after a brief illness, the immediate cause of his death being a stroke of apoplexy.

Mr. Pond was born in Woonsocket, R. I., on July 31, 1850. He received his primary education in the public schools of Woonsocket and then entered the Massachusetts Institute of Technology, graduating in mechanical engineering in 1874.

After graduation, he took a position as draftsman with the Woonsocket Machinery Co., later being promoted to assistant foreman. He then became Assistant Superintendent of the Brownell Co. plant at Dayton, Ohio, and from there went to the Isaac V. Holmes Co. of Cleveland, as Designing Engineer.

In 1878, Mr. Pond came west to St. Louis and organized the Pond Machinery Co., acting also as St. Louis representative of the Henry R. Worthington Co. In 1899, he came to Chicago and under the firm name of F. H. Pond & Co. took up the Chicago agency of the Chuse Engine & Mfg. Co., which position he held at the time of his death.

He became a member of the Western Society of Engineers, January 12, 1914.

Although of a retiring and unassuming disposition, Mr. Pond was known among his friends as an engineer of ability and a man whose standard of personal and business honor might well serve as an example to the younger men entering the profession.

On July 6, 1881, Mr. Pond married Elizabeth C. Chappell and to them were born three children—Ethel J., Mabel M. and Frank H., Jr., of whom the daughter Ethel and son Frank survive him.

Memoir prepared by Fred J. Postel, Andrew Allen and A. J. Saxe, Committee.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

VALUE FOR RATE-MAKING. By Henry Floy, Consulting Engineer. McGraw-Hill Book Co., New York, 1916, 325 pages, 6 by 9 inches. Price, $4.00.

Most of those interested in rate-making are familiar with the author's book, "The Valuation of Public Utility Properties," published about four years ago. In the preface of the new book, the author, referring to the old book, says: "Since that time, several other books have been published, many papers written and much discussion elicited, due to the development of a rapidly increasing general interest in the subject of valuation of utility properties, for the purposes of purchase or sale, rate-making, taxation or capitalization. Despite this activity, it is a disappointment to observe that terms are still used inexactly and opinions are almost as diverse and numerous as there are writers."

In view of the diverse opinions held with relation to the report of the Valuation Committee of the American Society of Civil Engineers, the gigantic task of the valuation of the railroads by the government, and the numerous other cases which will occur to the reader, it would be too much to expect a book of this kind to satisfy all of its readers, but those who wish to be informed on the subject cannot afford to omit reading it.

The purpose of the book, as stated by the author, is to emphasize the following principles:

"First—To conform to the rulings of the courts the basis for rate-making should be the fair present value of the property used, regardless of the amount of the original investment in utilities established previous to the present public regulation regime.

"Second—Present value for rate-making is obtained by making deduction for absolute depreciation only; ignoring theoretical depreciation. Absolute depreciation being that deterioration which is in evidence, existing and determined by inspection. Theoretical depreciation being estimates only, based on assumptions and computations.

"Third—Practically every utility property includes certain intangible non-physical elements, which should be evaluated and allowed in addition to the material, sensible elements. The value of the non-physical parts may vary from a few per cent to a hundred per cent or more of the value of the physical parts of a property."

The contents are as follows:

Chapter 1—Introduction.
Chapter 2—Definitions.
Chapter 3—Fundamentals in Valuation.
Chapter 4—Fair Value for Rate-Making.
Chapter 5—Cost of Reproduction.
Chapter 6—Land, Paving and Water Rights.
Chapter 7—Franchises, Working Capital and Bond Discounts.
Chapter 8—Going Value.
Chapter 9—Depreciation.

HYDRAULICS. By R. L. Daugherty, Asst. Professor of Hydraulics, Cornell University. McGraw-Hill Book Co., New York. 1916. Price, $2.50.

The author states that this book has been prepared as a text for stu-

dents who are required to cover a wide field in hydraulics in a limited amount of time. Attention has, therefore, been given principally to fundamentals, and there is a liberal use of diagrams, curves and half-tones, with a view of giving the student a mental picture of the physical facts. It is stated that in considering turbines and centrifugal pumps, the first essential is to give a fair idea of the general appearance, construction and arrangement of such machines, instead of plunging directly into a mass of equations. This does not mean, of course, that the subject of hydraulics is not treated mathematically, but indicates the method of approach.

Mechanical Engineers' Handbook. By Lionel S. Marks, Professor of Mechanical Engineering, Massachusetts Institute of Technology, Editor-in-Chief. McGraw-Hill Book Co., New York. 1916. 7,835 pages, 4½ inches by 7½ inches. Flexible back. Price, $5.00.

This handbook represents the work of about fifty specialists, under the direction of the Editor-in-Chief. It is modelled upon the three-volume German book "Hutte," and, in fact, arrangements were made with the publishers of the latter for the use of portions of the "Hutte." It was found necessary, however, to adapt them to American practice and conditions, so that the greater part of the book is new, while the best parts of the "Hutte" have been incorporated in a representative American handbook. The size and general appearance of the book are similar to the "American Civil Engineers' Pocket Book."

There is an excellent index of 54 pages.

Following is the table of contents:

Section 1—Mathematical Tables and Weights and Measures.

Section 2—Mathematics.

Section 3—Mechanics of Solids and Liquids.

Section 4—Heat.

Section 5—Strength of Materials.

Section 6—Materials of Engineering.

Section 7—Machine Elements.

Section 8—Power Generation.

Section 9—Hoisting and Conveying.

Section 10—Transportation.

Section 11—Building Construction and Equipment.

Section 12—Machine Shop Practice.

Section 13—Pumps and Compressors.

Section 14—Electrical Engineering.

Section 15—Engineering Measurements, Mechanical Refrigeration, etc.

Conservation of Water by Storage. By George F. Swain, Professor of Civil Engineering, Massachusetts Institute of Technology. Yale University Press, New Haven, Conn. Price $3.

This book, which is handsomely printed, illustrated and bound, is based on a series of lectures delivered by Professor Swain at the Sheffield Scientific School of Yale University. The first chapter is devoted to the general subject of conservation, the general conditions as to the use and waste of natural resources and the necessity for remedying those conditions.

This is followed by chapters devoted to the relation of the conservation of water to the conservation of other resources, with particular reference to the controversy on the question of the Federal control of water powers.

The author was chairman of the Water-Power Committee of the Fourth Conservation Congress held at Washington in 1913 and the results of his studies in that connection are, to a large extent, embodied in these lectures.

The lectures also deal with the engineering features of water-power development and with floods and their prevention.

They are a valuable contribution to the literature of the subject, particularly in its legal phases.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Meeting No. 937, May 1, 1916.

The meeting was called to order at 7:45 p. m., with President Grant in the chair and about 175 members and guests present. The paper of the evening, by Captain Henry B. Sauerman, M. W. S. E., on "Fortification," was read by Lieutenant Guilfoil, of Company A, Engineers, Illinois National Guard. The paper was discussed at length by Lieutenant H. S. Baker, Lieutenant Ernest McCullough and Messrs. J. W. Lowell, Jr., F. J. Postel, E. N. Layfield, D. A. Tomlinson and V. R. Walling, followed by closing remarks by Captain Sauerman. The meeting adjourned at 10:45 p. m.

Meeting No. 938, May 8, 1916.

The meeting was called to order at 7:50 p. m. by Chairman Lacher of the Bridge and Structural Section, with about 90 members and guests present. The Secretary reported from the Board of Direction that at their last meeting, the following had been elected to membership in the grades indicated:

Walter Painter, Oak Park, Illinois .... Member
Frank L. Orr, Des Moines, Iowa .... Student Member
Benno B. Sostheim, Chicago .... Junior Member
Orville H. Taylor, Beaver Dam, Kentucky .... Associate Member
John Stone, Chicago, Illinois .... Associate Member

The Secretary also reported that the following new applications had been received:

James S. Harvey, Jr., Chicago, Ill., transfer.
James E. Cahill, Chicago, Illinois, transfer.
Robert L. Fitzgerald, Winnetka, Illinois.
Robert L. Lewis, Batavia, Illinois.
Rudolph O. Branaugh, Chicago, Illinois.

And also that Frank H. Pond, M. W. S. E., had died on April 12, 1916.

The paper of the evening, "Operating Machinery of the Willamette River Draw Bridge Near Portland, Oregon," was read by the author, Mr. Byron B. Carter. The paper was discussed by Messrs. C. H. Norwood, Andrews Allen, H. J. Hansen, E. B. Bergendahl, J. C. Bley, William B. Jackson, F. G. Vent and the author, after which the meeting adjourned at about 10:50 p. m.

Meeting No. 939, May 15, 1916.

The meeting was called to order at 7:45 p. m. by President Grant, with about 50 members and guests present. The paper of the evening on "City Manager" was read by Mr. Gaylord Cummin, city manager of Jackson, Michigan, and was discussed by Messrs. W. F. Smith, J. W. Lowell, Jr., W. S. Lacher, E. N. Layfield, F. H. Cenfield, J. N. Hatch, N. M. Stineman, L. L. Holliday, J. L. Jacobs, George M. Ilg and N. P. Frandsen. The meeting adjourned at 10:45 p. m.

E. N. LAYFIELD,
Secretary.

Journal of the
Western Society of Engineers

Vol. XXI. JUNE, 1916 No. 6

RECENT STREET LIGHTING PROBLEMS AND DEVELOPMENTS

By J. R. Cravath, M. W. S. E.

Presented before a Joint Meeting of the Chicago Section A. I. E. E., Chicago Section I. E. S. and Electrical Section W. S. E., February 28, 1916.

In order to consider recent street lighting problems and developments in their proper light we must necessarily constantly refer back to the older conceptions of the street lighting problem, many of which older conceptions still exist in the minds of the lay public, and to some extent among the members of the engineering fraternity who have not closely followed street lighting matters.

The most noticeable change, to the layman, has been the change in the illuminants available. The open carbon arc lamp of 25 years ago gave way to the enclosed carbon arc lamp of lower efficiency and lower maintenance cost and this in turn is giving way to the luminous or magnetite arc lamp and the gas filled tungsten incandescent lamp. The low efficiency series carbon filament street lamp used up to about 10 years ago found but limited application in spite of the decided advantages of small units for the lighting of most residence streets. The series tungsten lamp, first in its vacuum and later in its gas filled form, has within the last 10 years worked radical changes in the possibilities of proper treatment of residence street lighting, and the multiple tungsten lamp is found on hundreds of miles of "white way" on business streets.

The competitive street illuminant, gas, has also been doing its share of progressive work the past 25 years; the first and most important change being the mantle burner in its upright form supplanting the flat flame open burner. Later the inverted mantle and improvements in burner construction as well as in methods of maintenance have kept gas from giving way entirely to electric street illuminants.

In the electrical field just at present the two kinds of lamps

which hold the supremacy are the gas filled tungsten incandescent lamp and the luminous or magnetic arc lamp with the new high efficiency electrodes. The flame arc lamp with long burning electrodes as used in Chicago and some other cities has shown such a decrease of candle power due to fouling of the globes between trimmings as to put it out of competition with the two other lamps just mentioned. Its initial efficiency, however, is high.

Ideas as to the proper methods of rating lamps for street lighting have undergone radical changes along with our increase of knowledge as to the actual photometric performances of lamps and their accessories. The old erroneous rating of 2000 candle power applied to the 9.6 ampere, 450-watt, open carbon arc lamp has been written into hundreds of street lighting contracts and in many cases has made trouble between municipalities and lighting companies. It is impossible to adopt any one rating that will properly value a lamp for street purposes as there are such varied conditions to be met on different kinds of streets. There is, however, substantial agreement among leaders in illuminating thought and practice that all lamps of whatever kind, whether for interior or exterior illumination should first be rated according to total lumens emitted; or upon what is the same thing differently expressed, viz., mean spherical candle power. This as a first step in uniform methods of rating is now being made and is a great improvement over the old methods of rating by candle power in some particular direction, said direction sometimes being chosen to best suit the desires of the lamp salesman. On account of incandescent electric lamps having been rated so long upon a horizontal candle power basis, and such candle powers having been included in many street lighting contracts, it is still the practice of the lamp manufacturers to give the horizontal candle power rating for series street incandescent lamps; but since the horizontal candle power of a gas filled lamp with a coiled filament is an exceedingly variable, and difficult to determine, quantity, the practice is to give the rated horizontal candle power as one-tenth the total lumens of the bare lamp. Thus a lamp rated at 100 horizontal candle power is a lamp giving 1000 lumens total light flux. This method of rating is approximately fair to all concerned, and in fact is about the only feasible way out of the difficult situation which arose when the introduction of coiled filament gas filled lamps rendered horizontal candle power measurements so erratic. Those engaged in writing street lighting contracts, however, should incorporate the foregoing stipulations as to how the horizontal candle power rating is obtained so as to avoid any possible future question on that point.

However, the rating of a lamp by total flux output in lumens of mean spherical candle power is now recognized as only the first step in ascribing the lamp a relative value for street illumination. It is important that the distribution of light flux be such that as large a percentage as possible is directed where it is most needed. The particular places where the greatest flux of light is needed or rather

the particular angles at which the greatest flux should be emitted depends on the height and spacing of lamps and the nature of the roadway or pavement. In general, it is a safe rule to follow to get as much of the flux delivered midway between lamps as possible. It is conceivable that this might be overdone; but not with present appliances or under any common present conditions of street lighting practice. Tests made by the street lighting committee of the National Electric Light Association and Association of Edison Illuminating Companies in 1914 and 1915 indicated that discernment of obstructions and obstacles along a street might be less with nearly uniform illumination coming from a number of sources than with less uniform illumination coming from a few larger sources. Conditions where an object can receive considerable light from a number of sources are only found on business streets and boulevards where the available expenditure per foot of street is much lighter than in residence streets. Residence streets contsitute the far greater mileage and the most important problems in street lighting, and call for the most intelligent planning to get the best results on account of the small appropriations available. On such streets, there is no present danger that the uniformity of illumination or the multiplicity of light sources illuminating any one point will be so great that quick or easy discernment is less than it would be with a smaller number of large sources. In such locations the main question is how far can the lighting units be sub-divided and be kept within reasonable expense limits.

The auxiliary appliance (consisting of globe, reflector, or what not), that delivers as much of the light flux as possible on the street midway between lamps (but not very much beyond that midway point), is likely to be by far the most economical for most conditions, and the use of proper equipment of this kind is important. As a second step, therefore, in our process of rating illuminants we must consider the lamp as equipped with whatever auxiliary appliance may deliver the flux of light in proper proportion along the street for the given conditions in question.

Along with the rating of lamps comes the question of depreciation of the lamp under actual service conditions below the performance of the same lamp in the laboratory when new. This necessitates consideration of the actual blackening or fouling of globes in service and the amount that depreciation in service may be prevented by proper cleaning and maintenance. This depreciation is much more serious than commonly supposed, and should be watched. This brings us to the question of contract relations between lighting companies and municipalities, to insure proper maintenance. The time honored form of contract is to stipulate a certain candle power of lamp to be operated according to a certain lighting schedule at a flat rate of so much per year. In some contracts this has been wisely modified to stipulate a certain type and kind of lamp with possibly some further stipulations as to operating con-

ditions and maintenance. Maintenance stimpulations in most contracts are decidedly weak.

It was at one time proposed, and in fact recommended, by the 1907 and 1908 committee of the National Electric Light Association on street lighting, that street illumination be sold on the basis of the illumination obtained on a vertical plane about midway between the lamps. This recommendation, however, did not find favor in practice, and it is perhaps fortunate that it never did as it confuses the question of lamps and systems of illumination in an undesirable way. In 1913 a committee of the same association recommended that the desirable form of contract should specify definitely the kind of lamps and their performance, leaving the question of the proper spacing, equipment, height, kind of lamp, etc., to be determined in advance of the contract. Under such a procedure the lighting company would contract to maintain and operate certain specified types of lamps up to a certain specified standard of service determined by candlepower tests. It might be specified that such tests be made on the streets or by removal of street lamps to the laboratory and operating them in the laboratory under as nearly as possible actual street conditions. Such contracts should not be entered into, however, without a full knowledge of the actual street performance of the lamps in question. Extensive experience in checking street performance against the performance of new lamps in the laboratory causes me to urge extreme caution in this respect, as the discrepancies between these two performances are great in most cases. However, in some cases the existence of street performance tests has had a very marked effect in improving maintenance conditions. This improvement has sometimes been fully equal to that of a much heralded improvement in efficiencies of lamps as accomplished by the manufacturers. Lamp efficiency, therefore, is both a manufacturing and an operating matter, and every large contract should have some check on maintenance.

As to the broader economic aspects of street lighting contracts there have been some interesting recent developments. Public utility commission regulation in many states has helped to remedy conditions of over charge and under charge for street lighting service. Assuming that a public utility commission does its duty in a theoretically perfect manner, municipalities should pay continuously the actual cost of street lighting service, including the depreciation caused by obsolescence of street lighting lamps and apparatus due to the rapid changes in the street lighting art. Such ideal conditions, however, have rarely been found in practice as yet, and most critics are paying too much or too little for such service. In order to provide flexibility in a street lighting contract a few contracts have been drawn, under which the city pays on a kilowatt hour basis much like a private customer. If the city owns the lamps, it is then free to change the size and type of lamp as often as it may see fit without the necessity of renewing a street lighting contract

or having a commission investigation. City ownership may even extend to circuits and poles with purchased energy. Equitable results should be obtained with either form of contract and the choice must depend largely on the relative flexibility of the two methods in any given case.

I have left the most important changes in our conceptions of what constitutes the real problem of street lighting until the last. How are lamps to be spaced, how high as they to be mounted, and how equipped as to globes and reflectors, to give the best discernment of objects along the street, with the best general appearance; or if the questions of easy discernment and pleasing appearance are not answered in the same way, what point of compromise shall be adopted? An early idea was that the effectiveness of a system of street lighting depended mainly on the total candle power of the lamp placed along a street without much regard for the height, distance apart, equipment, or size of each unit. Later, more scientific ideas were advanced, based on the illumination along the street. Ten or fifteen years ago, vertical illumination was the chief thing considered in street lighting. Later horizontal illumination on the street surface received more consideration. All of the following have been proposed as criterions for the value of a system of street illumination:

Minimum vertical illumination between lamps.
Average vertical illumination.
Minimum horizontal illumination.
Average horizontal illumination.

None of these is sufficient and all of these together would be incomplete for the reasons given later, *but* if one is selected as a practical working measure for residence streets at the present time, minimum vertical illumination between lamps would probably be as good a criterion as could be established, and minimum horizontal illumination for business streets, but these are far from taking into account all of the conditions which influence clearness of vision. In the year 1910 two memorable contributions to the literature and knowledge of a street lighting were made. One of these by Mr. Preston S. Millar, before the Illuminating Engineering Society, showed that a considerable portion of our seeing by street lighting at night is by virtue of the silhouette effect, whereby objects are seen as dark silhouettes against a light surface background. Illumination of the street surface rather than the vertical objects on it is necessary for this.

The other contribution was by Mr. A. J. Sweet in the Journal of the Franklin Institute, in which the blinding effects of glare were studied. The blinding effect of glare, that is, the effect of a row of lamps within the line of vision when looking along a street at night, renders ineffectual a certain percentage of the light expended upon the street for the purposes of illumination, because it decreases the ability of the eye to see. The existence of such an effect is easily demonstrated by anyone, but quantitative measurements of it were

first published in 1910 as stated, and have since been studied in more detail by Mr. Sweet.

We see objects along a street at night just as we see all objects at any time, namely, by virtue of differences in brightness and color of their surfaces. A study of silhouette effect in connection with this fact leads to some interesting results. As stated, a considerable portion of our discernment at night is by virtue of this silhouette effect. Fortunately, the reflection from paved surfaces is greatest at very oblique angles, so that, as shown by Millar, the brightness of a street surface is much more nearly uniform than would be indicated by a measurement of horizontal illumination. All this helps to make a uniform background for a silhouette effect.

The avoidance of glare effect (which in common past practice may easily be such as to call for from 1.2 to 1.8 times the illumination that would be necessary if glare were not present), is partially accomplished by increasing lamp heights. Good practice now mounts lamps from 16 to 25 and even 30 feet in height, where formerly heights from 10 to 14 feet were employed.

As to how far it is feasible to reduce the blinding effect of glare materially by the use of refractors which reduce the flux of distant lamps entering the eye, without too much darkening of the street surface between lamps, is a point upon which conclusive demonstration may be looked for soon. That a partial solution of the difficulty is feasible there is no doubt.

I have been able here to touch but briefly on some of the more important points of this subject.

SOME EXPERIENCES IN CONNECTION WITH CHICAGO'S STREET LIGHTING SYSTEM

By Arthur C. King.

Presented Before a Joint Meeting of the Chicago Section, A. I. E. E., Chicago Section I. E. S. and Electrical Section, W. S. E., February 28, 1916.

The City of Chicago has been a pioneer in the development of municipal street lighting system, particularly during recent years. Owing to the magnitude of the system and on account of local conditions, it has been found advantageous, and in some cases necessary to do considerable experimental work before adopting any system as a standard. The results of the trial installations and tests were incorporated in specifications for the manufacture of lamps and apparatus of a higher standard than the market afforded at the time, so that it may truthfully be stated that the development of the art has been advanced through the efforts of the Electrical Department of the City of Chicago. This was the case when the seven ampere enclosed series a. c. arc lamp was adopted as a standard, about 1903, and also in 1911, when the ten ampere series a. c. flame arc was standardized for all new installations.

Early in 1914, immediately after the nitrogen-filled tungsten lamp was announced, the department installed a number of trial lamps in series with flaming arcs. This trial installation and the results of other investigations were so satisfactory that the department felt justified in contracting for the installation of 2,000 lamps, rated at 600 candle power, 20 amperes, one-half watt per candle, including fixtures of its own design, housing a compensator for increasing the line current from either 10 amperes or 6.6 amperes to 20 amperes.

From the strictly theoretical standpoint, the type "C" incandescent lamp in a pendant fixture and equipped with a clear globe having an efficiency of 12 downward lumens per watt does not compare favorably with the flaming arc delivering 17.5 lumens per watt under the same conditions. However, experience has demonstrated that the average results obtained from the arc lamp in service do not approximate those contained by test by a wide margin, while the incandescent lamp is just as efficient in actual service on the street, as under test conditions, if the glassware is properly maintained. Tests under operating conditions in Chicago have shown that the absorption of light of the flame arc, due to etching of the inner globe and the accumulation of the products of combustion, averages about 40%.

The actual service tests and observations on the first type "C"

installation demonstrated that under *average* conditions, the effective illuminations derived from the 320 watt unit was nearly, if not fully, equal to that of the flaming arc, consuming 465 watts.

Other conditions peculiar to the Chicago situation render the

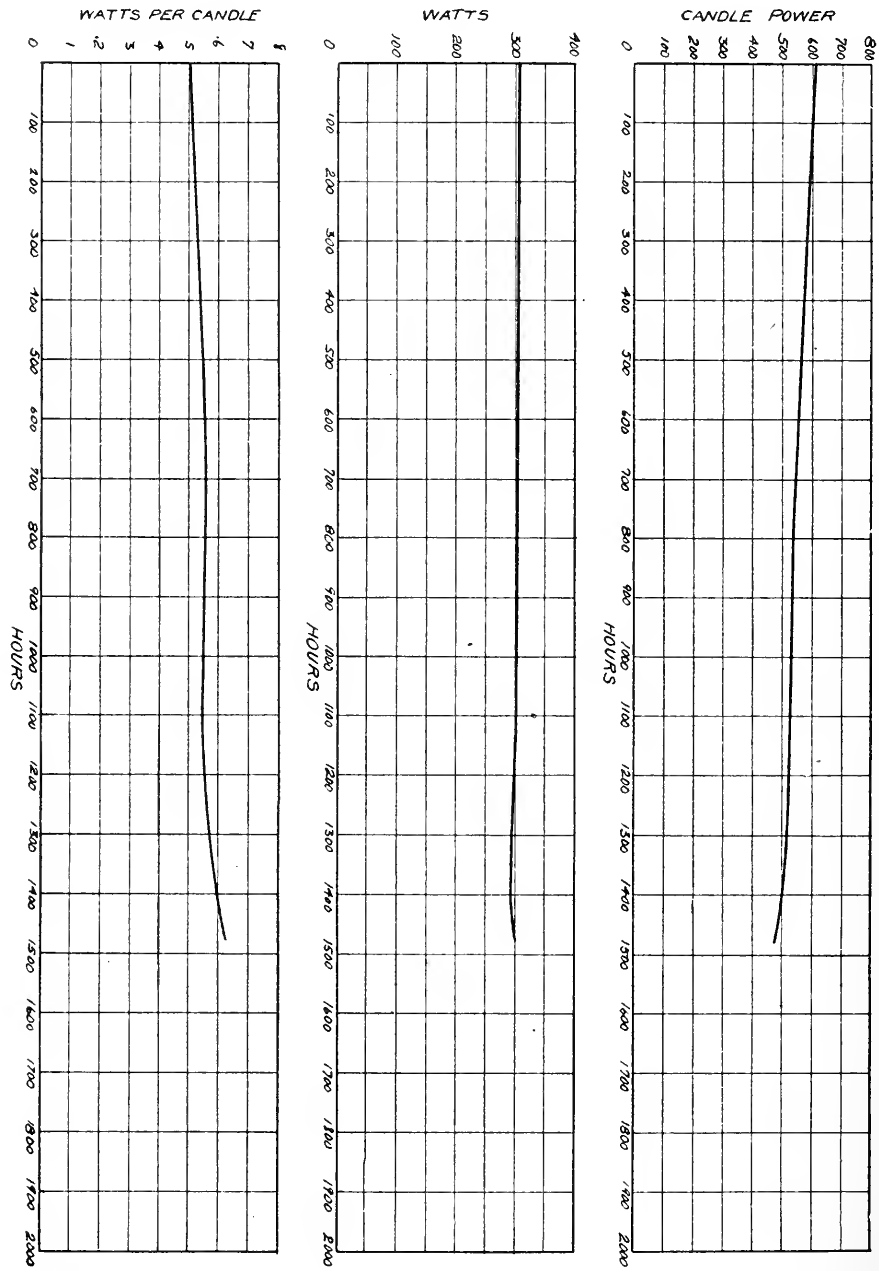


Fig. 1. Type "C" Life Performance 600 c. p. 20A.

type "C" lamp especially advantageous. Under a contract made in 1910, the Sanitary District of Chicago undertook to rehabilitate the old lighting system, consisting of about 5,300 open d. c. arcs and 6,000 a. c. enclosed arcs, and to install in addition 10,000 arc

lamps of 450 watts each, or the equivalent in other units. As the department was dependent on this contract for the financing of the system, the employment of a unit of low wattage, delivering a satisfactory amount of light, was essential. Owing to the reduction in wattage and increase in power factor of the lamp circuit from 82% to 98%, it was found possible to lay out circuits for 100 lamps instead of 65, which was the previous standard for flame arc operation, with no change whatever in the substation equipment. This naturally results in a greatly reduced investment per unit for substation apparatus and feeder cable, while the cost of the lamp and

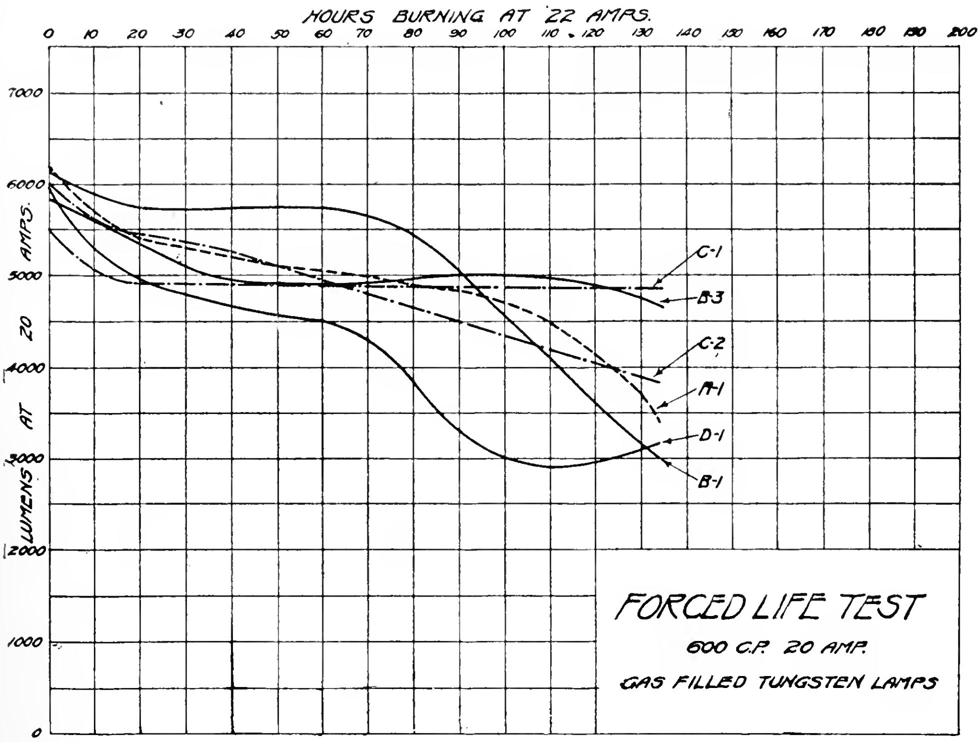


Fig. 2.

fixture complete is only about one-third that of the arc. The resulting saving in fixed charges due to decreased investment were partially offset by higher cost of lamp renewals, as compared with carbons, but, on the other hand, the lamp repairs and labor of maintenance was greately reduced. Even though there appeared to be no saving in the total annual charges, the experience of the past few years indicates that the ordinary depreciation charges on street lighting systems have been considerably underestimated, owing to the large and uncertain factor of obsolescence, so that other conditions being equal, even though what is ordinarily estimated as good practice in depreciation accounting be taken into consideration, the cheapest equipment is in the ultimate analysis the most advantageous to install. This, together with the realization that the logical

ultimate development would be along the line of an a. c. rather than a. d. c. unit, rendered the magnetite lamp unsuitable for a large system in the opinion of the department's engineers.

Naturally, the two most important considerations in the operations of the type "C" lamps is the life of the lamp and the maintenance of its efficiency. After elaborate tests of the circuit conditions prevailing on the system, the lamp manufacturers guaranteed an average lamp life of 1,000 hours. The performance of the earlier lamps indicated that the guarantee as to life would be materially exceeded while the efficiency was well maintained. Fig. 1 shows the average results obtained from a number of lamps operated in the laboratory under normal conditions. Fig. 2 shows the

	Sub-Sta. No.	CKT No.	CKT Position No.	Test Lamp	Mfr.	Type	Purchase Lot No.	Order in Service	IN SERVICE Hour	12 Mo. 11	Yr.	OUT OF SERVICE Hour	12 Mo. 11	Yr.	Net Hours In Service	Service Status	De-fects City	Mfg.	
00000000	00	000	000	0	0	0	00	00	0000	10	0	0000	10	0	0000	0	0	0	000
11111111	11	111	111	1	1	1	11	11	1111	1	1	1111	1	1	1111	1	1	1	111
22222222	22	222	222	2	2	2	22	22	2222	2	2	2222	2	2	2222	2	2	2	222
33333333	33	333	333	3	3	3	33	33	3333	3	3	3333	3	3	3333	3	3	4	333
44444444	44	444	444	4	4	4	44	44	4444	4	4	4444	4	4	4444	4	4	4	444
55555555	55	555	555	5	5	5	55	55	5555	5	5	5555	5	5	5555	5	5	5'	555
66666666	66	666	666	6	6	6	66	66	6666	6	6	6666	6	6	6666	6	6	6	666
77777777	77	777	777	7	7	7	77	77	7777	7	7	7777	7	7	7777	7	7	7	777
88888888	88	888	888	8	8	8	88	88	8888	8	8	8888	8	8	8888	8	8	8	888
99999999	99	999	999	9	9	9	99	99	9999	9	9	9999	9	9	9999	9	9	9	999

Fig. 3.

results of a number of tests to determine the characteristics of lamps under abnormal conditions, the lamps being operated at 10% above rated current. It is interesting to note that while the individual lamps show widely varying characteristics, all experience a rather sudden initial drop in total light flux during the first 20 hours. This is due to abnormal distortion of the filament on account of the extremely high operating temperature under these conditions.

Tests of a number of lamps which have burned in excess of 4,300 hours in regular operation show an average efficiency of 10.9 lumens per watt, or 64% of the initial value. These lamps were originally somewhat lower in efficiency than the standard rating. The filaments of these lamps have elongated to about double their original length, due to stretching of the coils, and have become so crystallized that they fracture very easily. The crystalline structure is very apparent to the naked eye. The loss in efficiency is due to these changes which effect a greater convection of heat from the filament, as well as due to the blacking of the globe.

The performance of the first 2,000 lamps and fixtures installed was so satisfactory that the remaining units to be installed by the

Sanitary District under the contract were ordered under the same specifications. On January 1, 1916, there were 12,275 of these units on the system, and it is estimated that there will be 15,863 in operation on completion of the contract within a few months.

The problem of keeping adequate records of lamp performance in a system of this size as a check on the manufacturers' guarantee as well as for operating statistics, is one of no small magnitude.

It was decided that a complete record should be kept of the lamp performance of 15% of the total number of installations, so selected as to obtain information which would be typical of the entire system. In order to facilitate the obtaining of all information which might be desired, the Hollerith tabulating system was

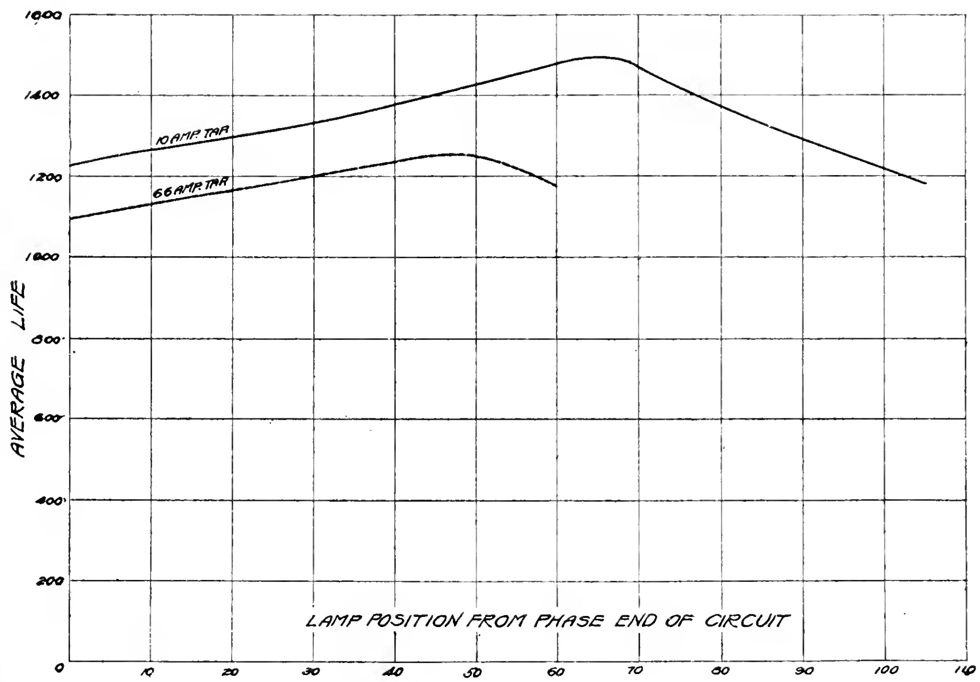


Fig. 4.

employed, for which the card shown in Fig. 3 was designed. As an illustration of the data which can be derived in this manner, Fig. 4 shows the average lamp life for the various locations of lamps on the circuit with respect to the phase end. At this point, it might be well to explain that in the Chicago system all circuits in the substation are operated from a common 8,750-5,050 volt 4-wire, 3-phase system, the neutral being grounded at the substation, each circuit being fed from one phase through a single pole oil switch, ammeter and G. E. type S. A. reactance regulator, to the lamp circuit and returning to the neutral bus. In the case of long circuits of underground cable with a line current of 4 or 6.6 amperes, the charging current has been found to be a rather large percentage of the total line current. Owing to the circuit being grounded, the

capacity current is supplied entirely from the phase end, resulting in a greater current and consequently brighter lamps near the phase end. Under these circumstances, the life of the lamps would be greater near the grounded end. With this scheme of connection, grounds on the circuit cut out the lamps between the point of trouble and neutral lead so that, on the average, the lamps near the

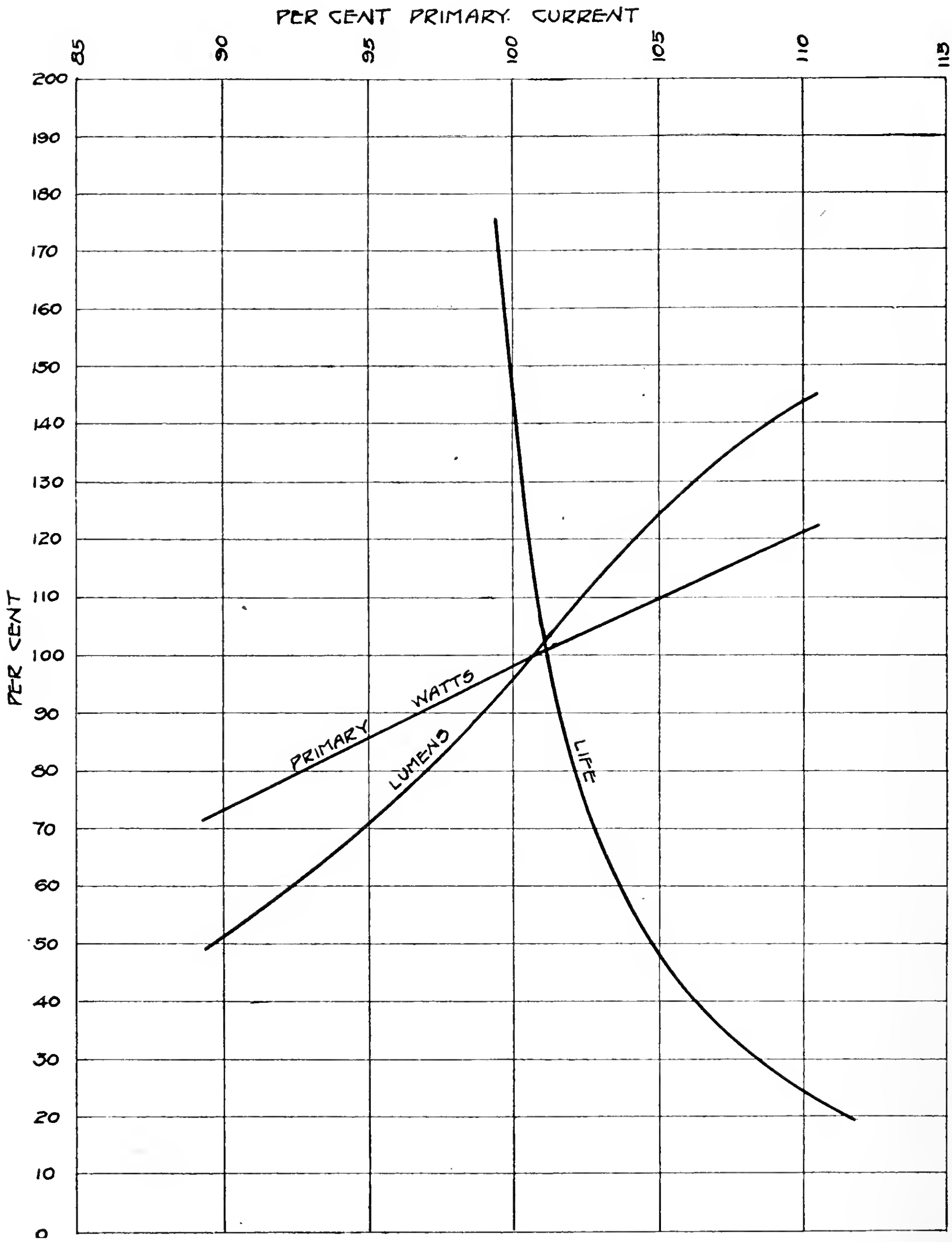


Fig. 5. Composite Curves.

Life, Lumens and Watts—Line Current. 600 c. p. 300 w. Type "C" Lamps. 6.6 Amp. Compensator Tap.

phase end would be burned a slightly greater number of hours in a given period of operation, and consequently the apparent life reduced. Under ordinary conditions, this difference would be slight.

Up to the present time, the 300 watt incandescent lamps have been installed on circuits which were largely aerial, carrying ten amperes normally, so that the capacity effect is negligible. When long underground circuits of these lamps are installed, it is proposed to insert reactance in the circuit near the grounded end to neutralize the component. This has been done in the case of long 4 ampere underground circuits feeding incandescent lamps, and the current in the line equalized, so that it is practically uniform throughout. It will be noted, however, that the curves show longer average lamp life near the center of the circuit than at either end, the exact reason for same not being apparent at the present time. However, these results would be expected on underground circuits, operated without grounds. The life of lamps operated from 6.6 ampere circuits appears to be shorter than that of the lamps on the 10 ampere circuits. This is because the 6.6 ampere circuits have been changed from arc to type "C" lamps within a year, and the long-lived lamps are still burning and consequently are not included in the average.

In order to determine the effect of changes of line current on the operation of the system, data have been prepared showing the variations in lamp life, total lumens, cost of energy, lamp renewals, operation of circuits, etc., with varying line currents. Figures 5 and 6 show percentage of normal primary watts lumens and life with varying percentages of primary current in the 6.6 and 10 ampere taps in the compensators. These bring out prominently the close regulation necessary to obtain satisfactory illumination as well as life of the lamps.

The annual cost per 1,000 lumens is shown in Fig. 7, being derived from our low energy cost of $15.00 per h. p. year. Operation and maintenance costs and fixed charges are as follows:

Operation and Maintenance (fixed).		*Fixed Charges.*	
Substation operation	$ .70		
Globes	.14	Ground rent	$ .06
Repairs to lamps	.13	Office rent	.04
Cleaning, trimming and patrolling	4.74	Lost taxes	2.58
Repairs to circuits, posts, etc.	4.66	Depreciation	7.98
Miscellaneous	.07	Interest	6.28
Supervision	.35	Miscellaneous	.06
Total	$10.79	Total	$17.00

It is seen that a minimum cost per unit is obtained at about 101% of normal primary current when all charges are included, while the corresponding figure when only cash costs are included, is 98%. This latter is doubtless the better operating value, as a greater factor

of safety is afforded against sudden circuit disturbances and sluggish action of the regulators.

The introduction of the type "C" lamp gave an impetus to the application of refracting glassware for street lighting, as the lamp was free from objectionable corrosive vapors, ash, etc., and had an absolutely fixed light center.

Characteristics of the 320 watt lamp unit complete fixture are

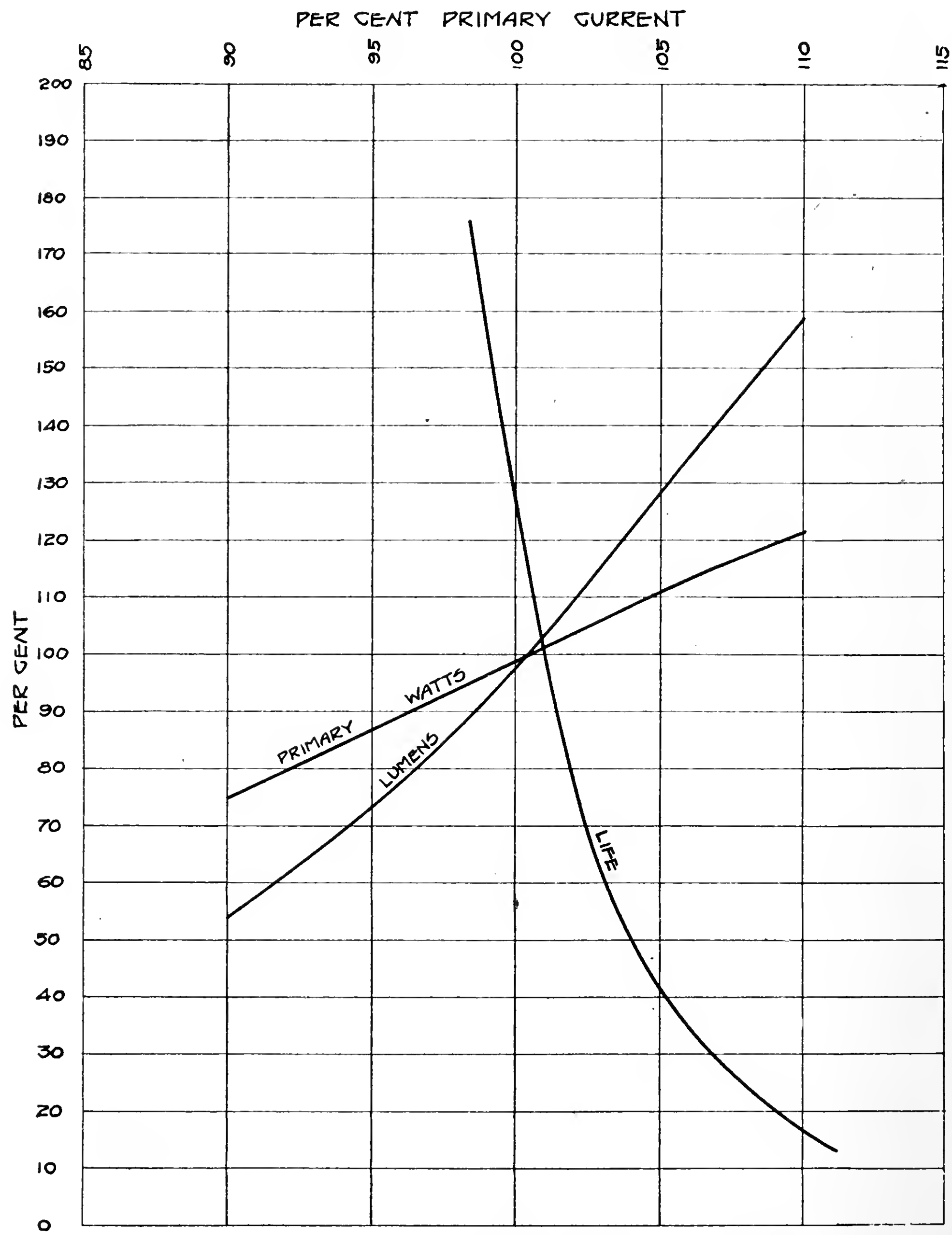


Fig. 6. Composite Curves.

Life, Lumens and Watts—Line Current. 600 c. p. 300 w. Type "C" Lamps. 10 Amp. Compensator Tap.

shown in Fig. 8. Curve "A" shows the distribution with bare lamp, "B" with alba outer globe and "C" with refractor. The efficiency of the diffusing globe is about 75%, while that of the refractor is 85%, while the distribution of light afforded by the latter is better from the theoretical standpoint. The use of prismatic glassware with these characteristics has not been deemed advisable as a standard by the department, although it has been given a trial.

The characteristics of the refractors are nearly ideal for small

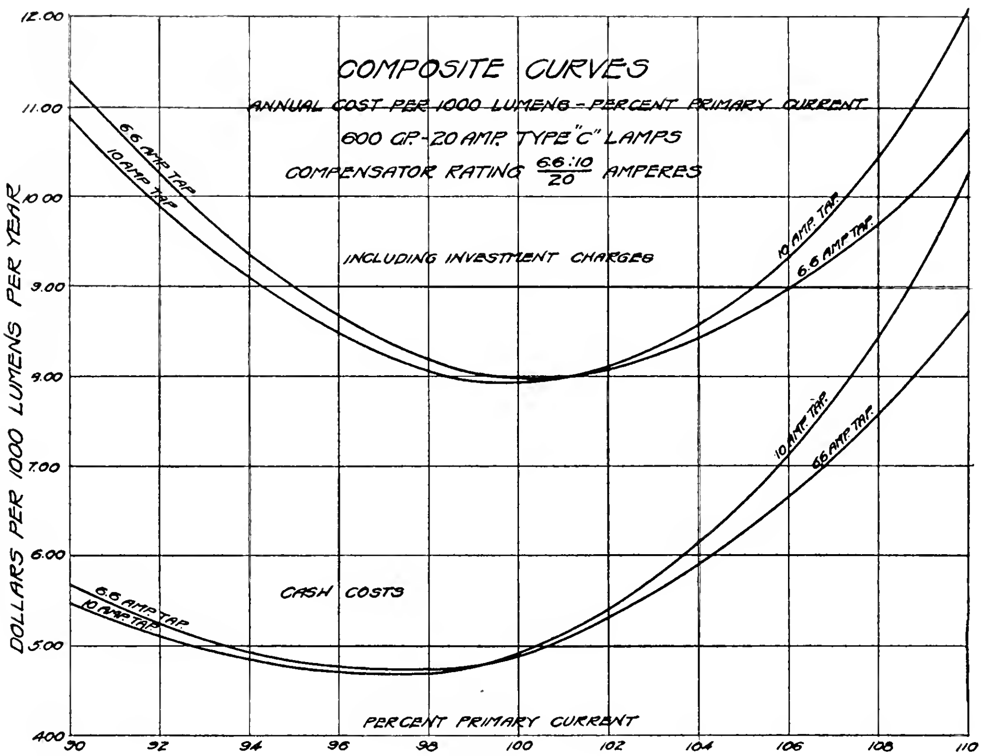


Fig. 7.

communities where lamps are suspended above street intersections with large linear spacing, where the streets are forested sufficiently to afford protection to adjacent buildings. In Chicago standard construction, the lamps are hung from a 30-in. bracket, and dense foliage is the exception rather than the rule, even on residence streets, while the buildings are generally located close to the curb. These facts render the use of the prismatic glassware with its high peaked distribution curve inadvisable in residence districts, as too much light is directed toward the buildings. Under our conditions, with lamps close to buildings, a calculation shows that diffusing glassware delivers slightly more useful lumens than the refractor, while suspended above the center of the street intersections the reverse is true. In this calculation, all light which is delivered higher than 6 feet above the inner edge of the sidewalk is considered as wasted. The use of an asymmetrical refractor which delivers the maximum light in a di-

rection parallel with the street naturally suggests itself, but this does not seem practicable, where the lamps are arranged to lower and free to rotate, as is largely the case here. Experience with the flaming arc lamp has lead to the adoption of diffusing glassware as a standard.

The relative intrinsic brilliancy of the refractor unit is 35 c. p. per sq. in., while the value for the diffusing globe is only 5.7. The number and insistence of complaints received from residents of streets illuminated with diffusing units is evidence that the light directed on building fronts in residence districts is worse than wasted.

During the six months from May to November, 1915, the de-

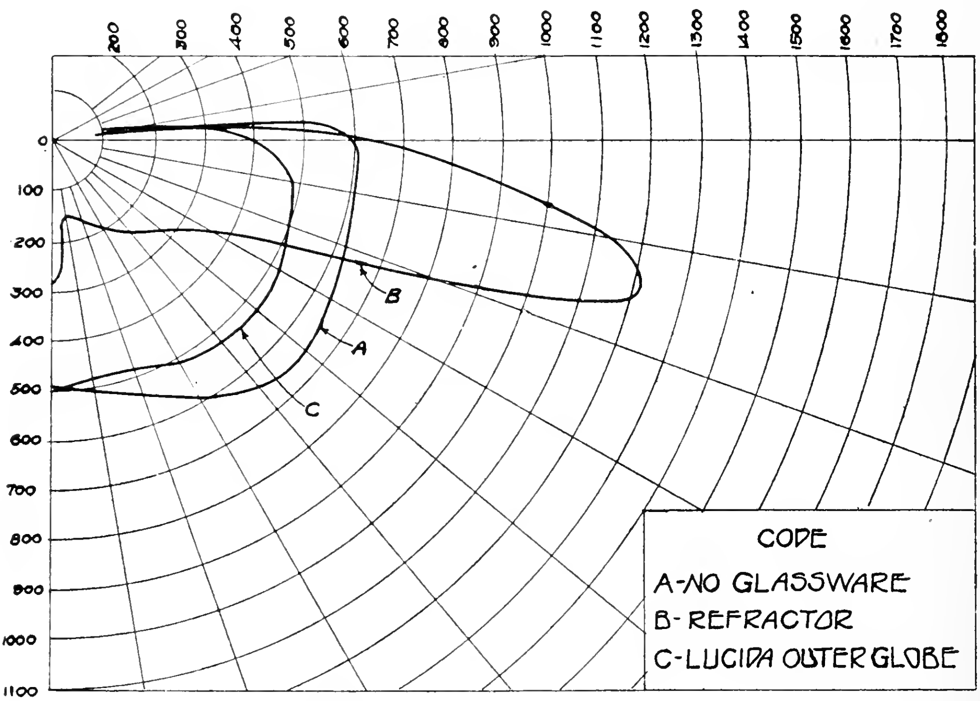


Fig. 8. Candlepower Distribution Curve. 300 w. Type "C" Lamp Fixture.

partment had requests for shading 226 street lamps, and in addition, removed 184 which had been placed without its sanction. The question had become so difficult to handle satisfactorily that this department was instrumental in having an ordinance passed, providing for the installation of approved shades at a fee of $2.00 each, with an annual maintenance charge of $1.00. This has resulted in a marked reduction in the number of shades installed, although the requests do not appreciably diminish.

The advantages of greater uniformity of illumination obtained by the use of the refractor, together with the illumination of the bright spot directly surrounding the lamp, are to a considerable degree theoretical, as under ordinary conditions direct illumination is not the controlling factor in the ability to distinguish objects,

which is the real test of street illumination. This is well illustrated by comparing the ability to distinguish objects on the same street on rainy nights as compared with dry, where the surface of the pavement is black when wet.

While the investigations and tests conducted by the department have largely been devoted to the 600 c. p. 20 ampere lamp, it has also adopted as a standard the gas-filled 4 ampere 75 watt 100 c. p. lamp. This lamp is used in connection with the ornamental residence lighting system in which the old gas lamp posts have been

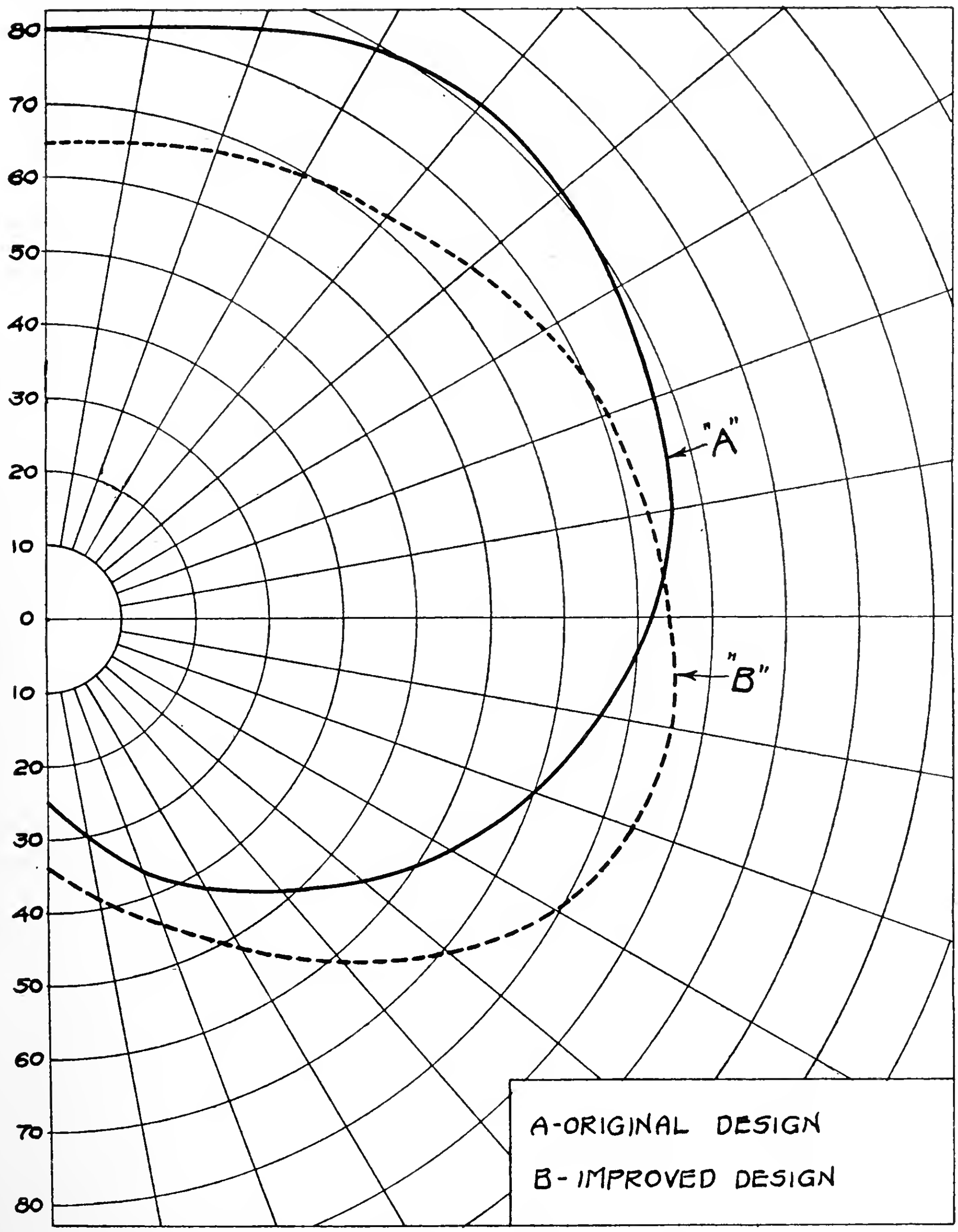


Fig. 9. Candlepower Distribution Curve. 100 c. p. Type "C" Lamp, 14 in. Alba Ball. Showing Effect of Filament Location in the Globe.

converted to electric standard by a specially designed head, carrying a 14-in. diffusing ball and fed from armored cable laid in the parkway. An 80 watt 80 c. p. vacuum lamp was formerly the standard lamp for these installations,—of which there are nearly 8,000 in service. Urgent requests by the department were responsible for the manufacturers developing a gas-filled lamp of this rating, which has proven very satisfactory as to life and maintenance of efficiency.

Figure 9 serves to illustrate the value of our illuminating engineering laboratory. Curve "A" shows the distribution from the unit as originally constructed which is typical for lamps mounted in spherical globes on tops of posts. With this mounting, tests showed that 59% of the total flux is directed to the upper hemisphere and consequently lost. By slightly changing the construction, the flux in the lower hemisphere has been increased about 19%, as shown in curve "B."

One important advantage of the Mazda lamp over the arc which has not heretofore been mentioned in the much smaller individual lamp outage. Comparative figures under actual operating condition in Chicago are as follows:

PER CENT OF TOTAL LAMPS

	Lamps Reported Out	Lamps Started or Replaced by Patrolmen on Route	Lamps out until following day
Flame arc	1.95	1.05	.90
600 c. p. Mazda............	.76	.27	.49
100 c. p. Mazda............	.39	.32	.07

The percentage of lamps started is not strictly comparative. A considerable proportion of both arcs and 600 c. p. Mazda lamps cannot be lowered, making it generally unsafe to attempt adjustments or replacements in operation. A greater percentage of the 600 c. p. Mazdas do not lower, so naturally the percentage started is smaller. The 100 c. p. Mazdas fixed are on short posts, but a device for safe removal has been worked out.

These data serve to emphasize the saving in labor of attendance as well as the better service obtained from the incandescent units.

The very low outage shown by the 100 c. p. units is largely due to the fact that a considerable number of the vacuum type lamps are still on the systems which have a greater average life than type "C" lamps.

PUBLIC SERVICE OPPORTUNITY AND PREPAREDNESS

By J. L. Jacobs.

Presented June 5, 1916.

Preparedness is the watchword of the hour. For almost two years this word has been ringing in our ears and has been set out before our eyes at every turn. As in the case of other epochs in the history of the world, it has required a colossal catastrophe to bring out the importance of preparedness as a safeguard for the economic, social and moral welfare of the individual and the state.

Yet to some it still remains a word limited and obscure in meaning. Those who perceive the immediate sense of the word conclude that preparedness means preparedness for war. The thinking majority have come to accept the broader view: that it means preparedness for peace and for the industrial, social and intellectual development of the people and of this democracy.

In the discussion by present day leaders of the different political and social forces in this country, recognition has been given to the necessity of industrial preparedness.

Our President in his annual message to Congress last year emphasized this point, in this way:

> "While we speak of the preparation of the nation to make sure of her security and her effective power we must not fall into the patent error of supposing that her real strength comes from armaments and mere safeguards or written law. It comes, of course, from her people, their energy, their success in their undertakings, their free opportunity to use the natural resources of our great homeland and of the lands outside our continental borders which look to us for protection, for encouragement, and for assistance in their development, from the organization and freedom and vitality of our economic life."

Labor, represented by Mr. Samuel Gompers, President of the American Federation of Labor, in a statement issued in a recent conference of labor leaders in Washington, D. C., voiced the following program of preparedness:

> "We must have a preparation that means a comprehensive development of all the powers and resources of all our citizens.
>
> We must see to it that the great mass of the farmers and the workers in industry shall be thoroughly trained and organized. We must see to it that the military and naval forces of the country are controlled in the interests of peace, of justice, of democracy, and of humanity.
>
> There must be industrial, commercial, political, social,

moral, as well as military defense. Citizen soldiery must be established and extended. It must be democratically organized, officered, and controlled. We must put an end to the present wasteful and unfair administration of our military affairs."

And then comes our ex-president and greatest living private citizen, whose very life has been the personification of resourceful preparedness, with the following statement:

"Preparedness must be both of the soul and of the body. It must be not only military but industrial and social. There can be no efficient preparedness against war unless there is in time of peace economic and spiritual preparedness in the things of peace. Well-meaning men continually forget this interdependence. Well-meaning men continually speak as if efficient military preparedness could be achieved out of industrial and social chaos, whereas such military preparedness would represent merely a muscular arm on a withered body."

Success and industrial and social progress of government depends after all not alone on preparation of "things of war" and trained men for *military service.* Realization of the growing importance and complexity of problems of public administration carries with it the acceptance of the conclusion that government must also have a personnel trained and prepared for the *civil service.*

The ideals and actions of organizations of society are reflected in the ideals of government. Problems of government are mostly problems of industrial and social welfare. Government regulation of monopoly, government supervision and operation of transportation systems and other public utilities, conservation, abolition of unfair privilege, wages and employment, all these and hundreds of other problems are closely related to the problems of industrial and social progress. There can be no full preparation for industrial and social progress, unless there is preparedness of a trained and efficient citizenship for the public service.

Constitutions, statutes and ordinances do not make democratic government. Government is a living organization, represented by the hundreds of thousands of men and women in the public service, who should administer public affairs in a way reflecting the desires and wishes of the citizen body. The rapid centralization of population, the increase in demands of the people for new activities and additional services by government and the growing complexity of problems of public administration have brought us face to face with the problem of supplying a trained personnel prepared to administer governmental work efficiently and economically. As the administration of our federal, state and local affairs succeeds or fails in these, so shall it reflect on the efficiency of our citizenship, on our well being and on our industrial and social progress.

The surest guarantee of efficient and effective administration in the public service is the most ample preparedness of men and women who are interested in and trained for public administration

and who have at heart the social and economic welfare of the community and state. Unless there is provision for greater supply of a personnel which is fully prepared and which realizes and appreciates the importance of and growing opportunities in public service administration, there can be no full preparation for and solution of our industrial and economic social problems.

It is to bring out this need of preparedness for public-service administration that this paper is being presented. I am bringing to you some thoughts upon the subject because of the significance of the move for general preparedness which is absorbing the interest of thinking men and women throughout this country. These thoughts and suggestions are not original nor new discoveries of facts. It has been my pleasure during the past six years to be engaged in public administration and in studying the general trend of government. With all the rough roads and difficult passages, I can say without reservation that it has been enjoyable and instructive to myself, and from the number and character of friends and enemies I have made, I presume it has been profitable to the citizen body and the public service.

A survey of the trend of government, problems affecting our social evolution and economic existence is indispensable to the solution of these problems. It is not possible within the confines of this paper to handle this broad subject exhaustively or in complete shape. It is my purpose to present and bear briefly upon some of the more important matters.

In my judgment there has never been a time in the history of our country when the call to public service of trained men and women has been greater than at present. It is only as we understand the trend of governmental affairs and how fundamental are the issues now before us and those that will be forced upon us, that we shall meet those issues positively and effectively.

The engineer above all others will be called upon in the solution of big public problems and in the development of governmental administration, as he has been in the solution of military and industrial problems. In the military service, the engineer is called upon to reconnoiter and develop offensive and defensive enginering plans for the fighting forces and fighting machinery. Upon the engineer corps, the duty of arranging for the sanitation of the camp and for comfort and health of the military organization is placed. The engineer has been called upon to lead in the solution of problems of transportation.

No greater tribute could have been paid to the engineering profession than the recent request by the President of the United States for a citizen trained corps to prepare an inventory of the country's manufacturing and industrial resources as the first step in industrial preparedness. The engineers of this country were prepared. The patriotic and democratic pledge to undertake and complete this task is now being carried out through a committee, representing the

five national engineering societies—Chemical, Civil, Electrical, Mechanical and Mining—which have a membership of over 30,000 engineers. It is such preparedness for service to the country that offers the best insurance for responsive and effective results in public administration.

To engineers credit must be given for the great achievements in connection with the construction of railways and waterways, the construction and operation of our municipal and other public works, the extension of public improvements and in the development of economic and scientific methods in the conduct of the routine of public administration. The role, which the engineer has played in the administration of affairs of our governmental bodies, has been mostly that of close application to details of administration, the importance of which have not always been brought out or fully appreciated by the public. In spite of these handicaps and the restrictions ofttimes brought about by politics and the uninformed and misinformed officials, the engineer has brought into the civil service the spirit of workmanship and ideals of scientific management and has been the first to use and instill in the minds of others the necessity of management based on scientific method.

In making any statements of achievements already accomplished through the patriotic and unselfish services of engineers, I was not unmindful of the greater opportunities which are before engineers and other trained personnel in the further development of responsible and effective public administration. Engineers, because of their analytical training, their ability to obtain and stick to facts and to act with precision, their imagination and vision for new and big things and their genuine interest and spirit of public service, have in the public service almost a virgin field.

The entry into the public service of men and women of ability and sincerity of purpose, with high ideals and non-recognition of the negative things in the public service, will have the effect of bringing about positive and fundamental improvements in the administration of public affairs and will give further impetus to the increasing favorable attitude of the public toward governmental administration. Politics, incompetency, irresponsible and mediocre service and administration can find no comfort and cannot long survive where such conditions exist.

In order that government can compete with private interests and hold the even scales of justice between the great private corporations and the public, the most intelligent and best personnel is none too good to be in sympathy with and in the service of the public. The need of interesting a greater number of men and women in the public service and preparation for more effective administration, therefore, cannot be exaggerated.

There is still a portion of citizenship which is well meaning and honest and would like to see things well done, but which is ignorant of public affairs and administration, and skeptical and afraid of

government. This ignorant class is a constant menace to honesty and efficiency. Being skeptical it does not give the time nor interest to aid the efficient and honest and demand that government be strengthened and waste and inefficiency be scorned. Inefficient public administration is the inevitable result of uninterested and inefficient citizenship.

This is well brought out in the case of the unending activity of our legislative bodies in passing harmful and undigested legislation which is as fruitful of waste and inefficiency as any other cause. Yet the legislators who are responsible for this are returned time and again. The people continue to talk and complain, but do not act. The cry against "pork" and "legislative log-rolling" is not followed up effectively. The squeal unfortunately does not last long. When opportunity is offered to the citizen at the polls, he either does not use his prerogative of citizenship or votes without being fully informed. As our friend B. L. T. of the Chicago Tribune has said:

"John Jenkins was a Patriot,
He loved his native land;
He jumped into a big parade
And marched behind the band.

"And when the march was over,
With all his might and main,
He jumped into a voting booth,
And voted Pork again."

The sooner the public becomes informed and convinced that government is a serious and technical business and that the administration of it must be placed in the hands of trained and expert men, even better trained and more loyal to government than to private interests, the sooner will the present forces, which are responsible for ineffective and wasteful governmental administration disappear.

It is incumbent upon every man and woman who has a vote, or expects to have one, to understand the machinery by which the laws are made and administered in our cities, states and nation. He should know who are his representatives in the local board of aldermen or council, in his state and in the federal government and should follow the results of legislation and administration of public affairs. All actions upon public questions should be carefully scrutinized and if not approved, the representative or administrator should be advised and warned. With such display of interest and understanding, the representatives will soon change their tactics. Those who do not, will surely be supplanted by others who will truly represent an intelligent and understanding citizenship.

Individual interest and a little exertion on the part of our citizen body, and preparedness to exercise its public duty in electing

better representatives, is certain to be followed by more efficient legislation and effective administration.

In a discussion of the need for preparedness in and the opportunities for trained men and women in the public service, it is desirable to view the situation at close range. What are the tendencies of governmental growth? What do statistics show on growth and cost of governmental functions and activities? What is the extent and character of the public service in our cities, counties, states and federal government? What is the relative size of the public service as compared with our largest private business? What are the newer tendencies and opportunities in the administration of public affairs?

Analysis of these questions, in the manner of an inventory, discloses certain interesting and positive facts. While a complete survey and comparison of governmental development and quantity and nature of the public services in this country is rendered difficult because of the lack of information and data of a uniform nature, analysis of statistics and studies by the United States Bureau of the Census and by students of public administration, provides sufficient data to enable one to recognize the trend of governmental development and the demands by the public for more efficient and economical administration.

The following table taken from the 13th census of the United States shows the increase of total population of the United States in periods of 10 years since 1880 and the growth of urban population:

Population of the United States.

	1910	1900	1890	1880
Total number	91,972,266	75,994,575	62,947,714	50,155,783
Urban	42,623,383	30,797,185	22,720,223	14,772,438
Rural	49,348,883	45,197,390	40,227,491	35,383,345
Total percent	100.0	100.0	100.0	100.0
Urban	46.3	40.5	36.1	29.5
Rural	53.7	59.5	63.9	70.5

Out of a total population of 50,000,000 in 1880, about 15,000,000 or 29% were living in cities or other incorporated places of 2,500 inhabitants or more. In 1890 out of the total population of 63,000,000 about 23,000,000 or 36% were classed as urban. In 1900 the percentage of urban population increased to 41% and in 1910 out of the total population of 92,000,000 slightly over 43,000,000 or 47% are designated as urban population. These comparisons of growth of urban population during the past generation are in themselves conclusive. When it is considered that in 1800 only 3.9% or 210,000 of the total population of 5,300,000 in the United States at that time, had increased to 43,000,000 in 1910 or almost 47% of the total population of 92,000,000, no question of the tendency of concentration of population into compact centers remains. This movement has continued during the present century.

Additional interesting facts showing the tendency of govern-

mental growth are obtained by analysis of the wealth, debt, taxation and expenditures of the national government, states, counties and other incorporated places in this country.

Government statistics show that in the last ten years the cost of federal government has increased by 50%. In the same time the expenditures by individual states for administration of state activities have increased approximately 100%. Of the expenditures by cities and other incorporated places having a population of 2,500 and over, the increase in the 10 years between 1902 and 1913, has amounted to over 45%.

The value at the close of the fiscal year 1913 of properties and assets of funds, other than sinking fund assets, of the states, counties and municipalities aggregating $6,152,572,012 which was divided into $4,600,000,000 for land buildings and equipment and over $1,500,000,000 for properties of service enterprises owned by the municipalities.

The debt of federal government 48 states and minor subdivisions (less sinking fund assets) at the end of the fiscal year 1913 amounted to $4,850,460.713, or an average per capita debt of about $50.00. The *per capita increase* of public indebtedness of *municipalities was 40.2%* from 1890 to 1902 and *72.7%* from 1902 to 1913. The per capita debt for the nation *decreased 13.3%* from 1902 to 1913, while the per capita state debt *increased 17.8%* during the same period.

The summary of receipts, payments and cash balances of the national government, states, counties and incorporated places having a population of 2,500 and over, in 1913, are given in the census bureau statistics as follows: The aggregate receipts and cash balances for all governmental and non-governmental purposes of the federal government states, counties and cities having population of over 2,500 amounted to about $8,070,000,000. The receipts and governmental cash payments of the federal government amounted to approximately $950,000,000, while that of the states amounted to over $375,000,000. All the counties received and expended almost a like sum to all the states, that is $375,000.000. Our cities and incorporated places having a population of 2,500 or more, received and expended over $1,200,000,000 for direct governmental purposes during the same year. The total receipts and government cash payments for the nation, states, counties and cities and incorporated places having a population of 2,500 and over thus amounted to over $2,960,000,000.

To comprehend the extent and character of our public service, reference is necessary to the matters of control of public employment, the outlook for extension of positive civil service control, the divisions of the public service in the federal government, states, counties and cities, the present estimated salary and wage expenditures in the different services and a few examples of character of employment in the larger services.

The concentration of population, with the attendent rapid increase and growing complexity of problems of public administration in the cities and in the federal government, has brought about a new attitude toward government and toward the personnel assigned to administer these problems. Demands for efficiency and responsive administration have followed the days of battles for freedom and reform. The passage of the federal civil service law in 1883 was the first sign of reaction against the Jacksonian doctrine "to the victors belong the spoils" and of the realization of the need of a trained personnel in the civil service.

Recitals of conditions which existed in the civil service when distribution of jobs and appointments were made on the "regularity" of and "loyalty" to "party" and the "invisible boss" are picturesque and illuminating. As early as 1869, there appeared an article in the Atlantic Monthly by James Parton entitled "Uncle Sam's Treatment of His Servants." Referring to the scramble for jobs, it reads in part as follows:

> "I might dwell upon the waste, the anguish, the indecency, the degradation of this scramble. I might speak of men coming to Washington with high hopes and full pockets, who begin by living at Willard's and treating with champagne, then remove to a less expensive hotel, afterwards to a cheap boarding house, and finally, after subsisting a while at 'free lunches,' borrow money to go home, where they arrive haggard and savage. I might speak of the impossibility of making good appointments in such circumstances; of the much better chance that brazen importunity has at such a time than merit; of the greater likelihood that a noisy, eleventh-hour convert will get an office than a man who has borne the burden and heat of the day, but has omitted to come to Washington. . . . The great evil of the system, as it is seen at Washington, is that it compels the chief persons of the government to expend most of their time and strength upon a matter that properly belongs to subordinates."

This old order of things, when the public service was exploited with each change in political party organization has been largely overthrown. Where it still persists, there is a growing dissatisfaction and spirited protest by an increasing citizenship. Spoils and wasteful administration is gradually but surely being replaced by positive employment methods and more efficient administration through trained and expert men and women. Spoils politicians and advocates of invisible government are uneasy when light is shed on them. Changes as they come now are in the manner of complete amputations—irresponsible, invisible, inefficient legislation and administration being supplanted by responsible and effective administration.

With the increasing demands for new activities and for efficiency and economy in administration, the negative system of checking spoils and protecting the personnel from undue or improper causes is being supplanted by new requirements and broad construc-

tive reform in civil service administration. This constructive plan includes the establishment of standards and specifications of work requirements, the provision of uniform schedules of salaries and wages, the definition and standardization of examination requirements and regulations governing advancements on seniority and efficiency, training of official personnel, promotions, demotions, retirements, etc.

The urgency and necessity of definite, equitable and business-like regulation of public employment requires no argument. With standardization of personal service comes a higher grade of personnel, establishment of orderly and equitable process of promotion and general justice and fair dealing between employer and employe. These are conducive to effective and economical administration.

In a Chicago audience, it may be pardonable to call attention to the fact that the movement for standardization of public employment was first initiated by the Chicago Civil Service Commission over six years ago. The classification and standardization plan has been in effect here for over five years. Several of our state governments and a number of other municipalities are either now establishing similar merit employment plans or are engaged in intensive studies on this problem.

The Bureau of Municipal Research of New York City, which has been actively co-operating with the New York city and state officials in similar standardization work during the past few years, recently published a comprehensive review of this movement. The following quotations are interesting:

> "It may be said, that the organizations—federal, state, municipal— throughout the country recognize that one of the most important reforms in government is that comprehended within the standardization movement—constructive reorganization of employment control which will substitute positive standards and requirements of work for the present negative system of restrictive regulation."
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> * * *
>
> "The movement for standardization of public employments has not yet expressed itself in a general way. Real achievements have been made in many jurisdictions, the influence of which is beginning to be felt by every municipal government, the activities of which are broad and varied enough to make the employment problem an important one. A keen appreciation of the idealism as well as the practical side of the movement and its intimate relation to the efficiency of governmental agencies has been expressed by all the public and private agencies that have been consulted.
>
> "The work of the Chicago civil service commission seems to have left its impress more widely than any other single agency in the country. This is due in part to the fact that Chicago was the pioneer in standardization, and partly to the fact of its loca-

tion which has permitted the Chicago civil service commission easily to effect contact with cities both in the East and in the West, which have looked to it for direction."

The United States census reports indicate that in 1910 there were, in addition to our federal and forty-eight (48) state governments, 2,953 county governments and 2,402 municipalities and other incorporated places having a population of 2,500 inhabitants or more. In addition to these there are over 10,000 political sub-divisions, each having a population less than 2,500 inhabitants.

About 61% of the 480,000 positions in the federal service are now filled after civil service competitive examination. Only twelve of our forty-eight states and about two hundred and fifty (250) of the 5,355 counties and cities having a population of over 2,500 inhabitants have at least part of their public services under the civil service system.

In our federal service there were on June 30th, 1915, approximately 480,000 officers and employes, whose aggregate annual salaries amounted to about $400,000,000. Of the total, about 300,000 or slightly over 60 per cent of the officers and employers were recruited into the service after competitive examinations under the federal civil service rules.

Reference to the following list of some of the important technical and professional positions, which have been filled during the past ten years by competitive federal civil service examinations give an idea of opportunities in the higher grade positions and in a larger number of similar positions in the lower grades. The work and remuneration in these lower positions are attractive and the system of promotion opens a way to a career in the federal service:

Civil Service Examinations Held for Positions in Federal Service Paying Salaries of $3000 and Over:
June 1, 1906, to Date.

$4800 Assistant supervisor of accounts, Interstate Commerce Commission.
$4800 Chief mechanical engineer, Bureau of Mines, Department of the Interior.
$4800 Chief metallurgist, Bureau of Mines.
$4800 Chief petroleum technologist, Bureau of Mines.
$4800 Senior architect, Interstate Commerce Commission.
$4800 Senior civil engineer, Interstate Commerce Commission.
$4800 Senior electrical engineer, Interstate Commerce Commission.
$4800 Senior mechanical engineer, Interstate Commerce Commission.
$4800 Senior railway signal engineer, Interstate Commerce Commission.
$4800 Senior structural engineer, Interstate Commerce Commission.
$4800 Senior telegraph and telephone engineer, Interstate Commerce Commission.
$4500 Metallurgical engineer (for work in iron and steel), Bureau of Mines.
$4500 Professor of chemistry, Public Health Service.
$4500 Professor of pharmacology, Public Health Service.
$4200 Assistant supervisor of accounts, Interstate Commerce Commission.
$4200 Civil aand hydraulic engineer, Department of the Interior.
$4000 Assistant chief, Bureau of Chemistry, Department of Agriculture.

$4000 Chemical engineer, Bureau of Mines.
$4000 Chief irrigation engineer, Indian Service.
$4000 Chemist, Department of Agriculture.
$4000 Chief mine surgeon, Bureau of Mines.
$4000 Chief of drainage investigations, Department of Agriculture.
$4000 Chief of field service in rural education, Bureau of Education.
$4000 Chief of the Department of Medicine, Philippine Service.
$4000 Chief physical chemist, Bureau of Mines.
$4000 Epidemiologist, Public Health Service.
$4000 Metallurgical engineer (for work in iron-blast furnaces), Bureau of Mines.
$4000 Metallurgist (for work in low-grade ores), Bureau of Mines.
$4000 Mining engineer, Bureau of Mines.
Expert radio aid, Navy Department, $10 per diem.
Special aid in civic education, Bureau of Education, $10 per diem.
$3600 Aeronautical engineer, War Department.
$3600 Coal-mining engineer, Geological Survey.
$3600 Consulting mining engineer, Bureau of Mines.
$3600 Engineer of mine-safety investigations, Bureau of Mines.
$3600 Gas waste engineer, Bureau of Mines.
$3600 Law examiner, Bureau of Mines.
$3600 Metallurgist (for work with smelter fumes), Bureau of Mines.
$3600 Mining engineer, Bureau of Mines.
$3600 Organic chemist, Bureau of Mines.
$3600 Petroleum engineer, Bureau of Mines.
$3600 Senior inspector of car equipment, Interstate Commerce Commission.
$3600 Senior inspector of motive power, Interstate Commerce Commission.
$3600 Senior land appraiser, Interstate Commerce Commission.
Torpedo engineer, Navy Department, $9.60 per diem.
$3500 Assistant director, Public Roads, Department of Agriculture.
$3500 Associate physicist (qualified in engineering) Bureau of Standards.
$3500 Chemist qualified in physical chemistry, Bureau of Standards.
$3500 Chief bacteriologist, Department of Agriculture.
$3500 Chief, Section of Derived Products, Forest Service.
$3500 Pulp and paper engineer, Forest Service.
$3500 Special examiner and special agent, Department of Commerce.
$3500 Specialist in agricultural education, Bureau of Education.
$3500 Specialist in cotton classing, Department of Agriculture.
$3500 Specialist in home economics, Bureau of Education.
$3500 Specialist in industrial education, Bureau of Education.
$3500 Specialist in mental and nervous diseases, Philippine Service.
$3300 Oil and gas inspector, Department of the Interior.
$3250 Engineer of tests, Public Roads, Department of Agriculture.
$3250 Scientist in soil survey, Department of Agriculture.
$3000 Agriculturist, Department of Agriculture.
$3000 Agriculturist, in charge, Department of Agriculture.
$3000 Alloy chemist, Bureau of Mines.
$3000 Assistant chemist, Bureau of Mines.
$3000 Assistant director, Public Roads, Department of Agriculture.
$3000 Assistant metallurgist, Bureau of Mines.
$3000 Associate engineer-physicist, Bureau of Standards.
$3000 Associate statistician, Interstate Commerce Commission.
$3000 Chemical engineer, Bureau of Mines.
$3000 Chief food and drug inspection chemist, Department of Agriculture.
$3000 Civil engineer, Philippine Service.
$3000 Crop technologist, Department of Agriculture.

$3000 Designing engineer, Reclamation Service, Department of the Interior.
$3000 Designer of hulls, War Department.
$3000 Designer of marine engines, boilers, and machinery, War Department.
$3000 Electrical engineer, Geological Survey.
$3000 Electrical expert (wireless telegraphy and telephony), Navy Department.
$3000 Electrometallurgist, Bureau of Mines.
$3000 Engineer-physicist, Bureau of Standards.
$3000 Entomological assistant, Department of Agriculture.
$3000 Examiner of accounts, Interstate Commerce Commission.
$3000 Forest inspector, Forest Service.
$3000 Hydro-electrical engineer, Forest Service.
$3000 Indian reservation superintendent, Indian Service.
$3000 Logging engineer, Forest Service.
$3000 Marketing specialist (dairy products), Department of Agriculture.
$3000 Marketing specialist (grain), Department of Agriculture.
$3000 Marketing specialist (live stock and meats), Department of Agriculture.
$3000 Mechanical engineer, Public Roads, Department of Agriculture.
$3000 Medical inspector and surgeon, Philippine Service.
$3000 Medical supervisor, Indian Service.
$3000 Metallurgical chemist, Bureau of Mines.
$3000 Metallurgical engineer, Bureau of Mines.
$3000 Mine surgeon, Bureau of Mines.
$3000 Mineral technologist, Bureau of Mines.
$3000 Petroleum engineer, Bureau of Mines.
$3000 Pharmaceutical research chemist, Department of Agriculture.
$3000 Pharmacognosist, Department of Agriculture.
$3000 Pharmacologist, Department of Agriculture.
$3000 Physical chemist, Bureau of Mines.
$3000 Physiologist, Department of Agriculture.
$3000 Plant pathologist in citrus fruit diseases, Department of Agriculture.
$3000 Plant physiologist, Department of Agriculture.
$3000 Quarry technologist, Bureau of Mines.
$3000 Senior drainage engineer, Department of Agriculture.
$3000 Senior highway engineer, Department of Agriculture.
$3000 Soil scientist, Department of Agriculture.
$3000 Special agent (qualified as Latin-American expert), Department of Commerce.
$3000 Specialist in co-operative organization, Department of Agriculture.
$3000 Specialist in cotton testing, Department of Agriculture.
$3000 Specialist in marketing perishable products, Department of Agriculture.
$3000 Specialist in rural education, Bureau of Education.
$3000 Specialist in school and home gardening, Bureau of Education.
$3000 Specialist in transportation of farm products, Department of Agriculture.

In addition to the 480,000 positions in the federal service, there are to be considered the administrative services in our forty-eight states and in the counties, cities and other municipal sub-divisions in this country. Estimates of total expenditures of the states, counties and cities by the United States Bureau of the Census indicate that during the fiscal year ending June, 1910, over $2,900,000,000 was

spent for direct governmental purposes and over $2,500,000,000 was spent for non-governmental purposes.

Owing to lack of sufficient data on the divisions and organization of the services in these governmental divisions, it is not possible to set out definitely the exact number of positions in these services. Estimates have been made and these vary from 1,400,000 to 1,500,000 positions in these services, in addition to the 480,000 positions in the federal service, making a total of between 1,880,000 and 1,980,000 positions in the public service in this country. At the rate of increase of governmental activities, it is not improbable that before long the total number of agents required to administer the public affairs of our nation, states, counties and cities will exceed the 2,000,000 figure.

It is interesting to compare this figure with railroad employment statistics. During the year ending June 30, 1914, as summarized from the annual reports of railroad companies having operating revenues of more than $100,000 for the year and also of companies owning property operated under lease or other agreement by those carriers, there were employed 1,710,296 steam railroad officials and employes, whose aggregate wages and salaries amounted to $1,373,422,472 for the year.

Comparison of the figures of expenditures for salaries and wages and number of positions in the railroad service brings out clearly the greater importance and extent of the public service. When it is considered that for each adult employed there are on an average four dependents the further importance of the public service may be comprehended. Thus, there are at least in this country 8,000,000 people who are directly concerned in the opportunities in the public service. The creation of an available supply of trained men and women prepared and eager to serve and help solve the problems in administering public affairs will go very far toward awakening and interesting our other 90,000,000 citizens on the interdependence of our social, economic and industrial needs and public service preparedness.

The figures above cited are given to show the size and expenditure value of the public service. Opportunities for trained men and women in the public service may also be brought out by analysis of some of the positions in some of the larger local governments where the service has been standardized and the opportunities for a life career clearly indicated.

Charity begins at home. There are approximately 30,000 positions in the Chicago civil service. This is exclusive of the officers and employees in the park commissions, the county service and the sanitary district, all of which are operating as separate and distinct municipalities. The Chicago city positions and salaries are distributed as shown in the following summary of positions and salaries, as based on the city civil service classifications and appropriations included in the 1915 appropriation bill:

Summary Distribution of Positions and Salaries Appropriated for Chicago City Service in 1915.

(From charts prepared by municipal efficiency division.)

Class of Service	Number of Distinctive Titles	Total Number of Positions	Total Salaries	Average Salaries
Medical	56	615	$ 625,160	$1017
Engineering	86	378	695,359	1840
Clerical	76	1486	1,763,861	1184
Police	11	4715	6,293,768	1335
‡Operating engineering	22	352	448,023	1450
‡Operating engineering (Schools)	4	308	1,071,861	*
Fire	18	1954	2,879,259	1473
Library	17	193	174,840	906
Inspection	97	848	1,192,662	1406
Supervising	64	361	468,090	1297
Skilled labor	214	2883	3,503,050	**
Labor	13	5538	3,905,213	**
Total, under Civil Service	678	19,631	$23,021,146	$1183
Educational Service	..	8,153	10,259,048	.....
Law and Municipal Courts	133	573	1,093,200	1325
All other positions exempted from civil service	..	158	420,599	.....
Blanket salary appropriations	..	...	379,542	.....
Total positions and salary appropriations	811	28,515	$35,173,535	$1266

*Estimated amount for school engineman-custodial service was expended for salaries and wages of enginemen and such additional help employed by them personally in care, maintenance and heating of school buildings and grounds.

**Prevailing union rates of pay are paid by the city for skilled labor and current per diem rates are paid for common labor.

‡The term "Operating Engineering Service" as used in the Chicago classification applies to those employments in which the incumbents are required to operate, maintain and repair equipment and machinery used in the production of heat, light and power for buildings, etc., or the supervision of such work. A more proper and correct term for these employments would be "Engineman Service" or "Engineman-Custodial Service."

The Chicago city service has been under civil service for twenty-three years. With the exception of the officers and places of employment in the law department, municipal courts and heads of departments, all positions are filled after civil service competitive examinations. Positions in the educational department are not directly under jurisdiction of the city Civil Service Commission, but teachers employed therein are recruited after test of training and proficiency in the work to which they are assigned.

As a result of an intensive study made about six years ago by the efficiency division of the city Civil Service Commission, the entire service was standardized on the basis of duties and work requirements and the salaries provided for same were made uniform for all positions having substantially like duties and responsibilities. As a result of the adoption of the standardization plan, recognition was given of the importance of positive employment methods and of the principle of justice and equitable treatment to public employes. Lines of promotion were defined and automatic advancement in compensation based upon seniority and efficiency was assured.

The Chicago city service is divided into twelve classes, including the class having those positions which are exempt from the civil service provisions. Each class is divided into grades, comprising all positions having duties substantially of the same degree of responsibility and importance. Altogether there were in 1915, about 811 distinctive titles of positions. The number of positions bearing the same titles vary from one, as in the cases of the higher administrative or specialized positions, to several thousand, as in the cases of the police and fire services.

The following is a list of some of the higher grade technical, professional or administrative positions in the Chicago service which have been filled by civil service competitive examinations. In the larger number of instances, these positions were filled through promotion of employes who had entered the city service in the lower grades and were promoted after examination of their ability and efficiency and seniority in the service:

Class of Service	*Title of Position.*	*Annual Salary*
Medical Service	Assistant commissioner of health	$4500
	Medical director (Municipal Tuberculosis Sanitarium)	3500
	Bureau chief of medical inspection	3900
	Chief surgeon (Police)	3000
	Director of laboratory	3000
Engineering Service	Architect (Board of Education)	8000
	Assistant city engineer	5000
	Chief engineer (Board of Education)	6000
	City engineer	8000
	Engineer (Board of Local Improvements)	3600
	Mechanical engineer in charge	7500
	Superintendent of streets	5000
	Assistant chief engineer sewers	2700
	Assistant chief engineer streets	2700
	Assistant engineer waterworks construction	3000
	Chief architectural designer	4020
	Chief building inspector in charge	2700
	Chief deputy smoke inspector	3000
	City architect	4500
	Deputy commissioner of buildings	4500
	Electrical engineer in charge	2700
	Electric supervisor	3000
	Engineer of bridge construction and repairs	3000
	Engineer of bridge design	3600

	Engineer of bridges and harbor	5000
	Engineer of surveys (sub-divisions)	3000
	Engineer of water works construction	4000
	Engineer of water works design	3600
	Expert on system and organization	3500
	Fire prevention engineer in charge	3000
	Gas supervisor	3600
	Heating and ventilating engineer	2700
	Industrial chemist	3000
	School electrical engineer	2700
	Secretary and engineer (transportation)	3600
	Superintendent of construction	3000
	Superintendent of maps	4000
	Superintendent of sidewalks	3000
	Superintendent of water pipe extension	4500
	Supervising mechanical engineer and chief boiler inspector	3000
	Telephone supervisor	3000
	Third assistant superintendent of streets in charge of street repairs	3600
	Transportation supervisor	3600
	Valuation supervisor	2700
Clerical Service	Administrative Secretary (Municipal Tuberculosis Sanitarium)	4500
	Assistant city treasurer	5000
	Business manager (Board of Education)	6000
	Deputy city collector	4000
	Deputy comptroller and city auditor	4800
	Secretary (Board of Education)	10000
	Superintendent special assessments and ex-officio secretary Board of Local Improvements	4020
	Superintendent of Water	4500
Library Service	Assistant Librarian	3750
	Librarian	8000
Inspection Service	Bureau chief of food inspection	2700
	Bureau chief of sanitary inspection	3800
	Chief electrical inspector	3000
	Chief gas tester	2500
	Chief identification inspector	3000
	Chief street inspector	3000
	Department inspector (Police)	3600
Supervising Service	Examiner in charge of efficiency	4500
	Second deputy superintendent of police	5000
	Superintendent, House of Correction	3600
	Superintendent of compulsory education	4000
	Superintendent of repairs (Board of Education)	5500
	Superintendent of sewers	4000

New and larger opportunities are being offered in our municipalities and in the larger states for men and women who are trained in the distinct professions and occupations and who have experiences in problems of public administration.

The administrative services of New York city and of New York state are additional examples of the larger divisions in this country where the increasing demands for additional governmental

activities and effective administration have brought about marked changes for positive employment methods.

As a result of perhaps the most intensive and scientific study of public employment yet undertaken in this country, standardization programs have recently been proposed for both the New York state and New York city services. The adoption of these will have a revolutionary effect upon these services, as it has in other private and public institutions where positive employment reform and standardization have been applied. The results will be the improvement of opportunities for trained men and women to find careers in the official service and the introduction of business principles in administration.

About $200,000,000 is expended annually for salaries and wages of officers and employes in the New York state departments and those of New York city. This amount, it is estimated, is about one-tenth of the total annual expenditures for personal services by all the public services in this country.

In both the New York state and New York city services most of the positions are filled by competitive civil service examinations. Under the regulations now in force, opportunity for promotion from the lower grade positions is offered those who show special fitness and ability for the higher administrative offices and positions. An idea of the extent and diversity of public service in the various governments in this country, can perhaps be best obtained by an examination of these services.

The proposed classification of the New York state and city services have been prepared according to distinctive lines of work. The groups of those positions which require special training and professional or technical knowledge and experiences, are indicated in the following for both the New York state and the New York city services. Practically every occupation and profession is included. Each of the groups include a number of positions having distinctive titles for which are set up definite specifications of work requirements, qualifications and rates of compensation based upon efficiency in service and responsibility and importance of duties:

Classification of New York State and New York City Services.

New York State Service Tentative Dec., 1915.	New York City Service Proposed Dec., 1915.
Service and Name of Group.	*Service and Name of Group.*
Administrative Managerial	Executive
Departmental Manager	Executive Council
Institutional Manager	Commissioner
	Deputy Commissioner
	Executive Secretary

Service and Name of Group.

Clerical
- Clerical and Office Positions

Professional and Scientific
- Accountant
- Archeologist
- Bacteriologist
- Bank Examiner
- Botanist
- Chemist and Physicist
- Civil Service Examiner
- Dentist
- Engineer
- Entomologist
- Forester
- Geologist
- Horticulturist
- Industrial Mediator
- Insurance Examiner
- Lawyer
- Nurse
- Pharmacist
- Physician
- Statistician
- Veterinarian
- Zoologist

Social and Educational
- Educational Specialist
- Librarian
- Regents Examiner

Inspectional and Investigational
- Agricultural Inspector
- Corporation Tax Examiner
- Examiner of Local Assessments
- Industrial Inspector
- Inspector of Buildings
- Inspector of Engineering Works
- Inspector of Mechanical Appliances and Equipment
- Immigration Labor Inspector
- Institutional Inspector
- Public Service Inspector
- Social Investigator

Institutional
- Institutional Positions

Service and Name of Group.

Clerical
- Clerical and Office Positions

Professional
- Accountant
- Architect
- Bacteriologist
- Chemist and Physicist
- Dentist
- Dietitian
- Engineer
- Forester and Entomologist
- Lawyer
- Nurse
- Pathologist
- Pharmacist
- Physician
- Veterinarian

Sub-Professional
- Arboriculturist
- Computer
- Draftsman
- Instrumentmen
- Law Clerk
- Title Examiner
- Industrial Instructor

Inspectional
- Inspector of Buildings
- Inspector of Combustible and Blasting
- Inspector of Electricity and Lighting
- Inspector of Health
- Inspector of Licenses
- Inspector of Public Works
- Inspector of Repairs and Supplies
- Inspector of Weights and Measures

Investigational
- Civil Service Examiner
- Deputy Tax Commissioner
- Municipal Examiner
- Probation Officer
- Social Investigator
- Statistician

Institutional
- Institutional Positions

Skilled Trades
- Largely Union Labor

Custodial
- Largely Labor

Street Cleaning
- Largely Labor

The examples outlined in the above and the references to statistics and figures showing the extent and character of the public service bring out the importance and necessity for positive employment control in the public service and the opportunities for trained men and women in this large and growing field.

The views and conclusions brought out in the recent study by the City Club of Chicago on the ideals of contemporary life that the chief ideal of this nation is democracy and that Americans believe in free democratic and just government and a social and economic equity are evidences of what our citizenship thinks and expects. These ideals and beliefs are being vitalized into progressive policies and activities intrusted in the hands of government, and in a new spirit of citizenship.

In education there has been an adjustment to new conditions. Moral and civic training is being emphasized in our progressive educational schools. Professor Scott Nearing in closing his book on The New Education writes:

> "The spirit of new education is the spirit of service, the spirit of fair dealing, the spirit of growth for the individual and of advancement for society."

The tendency of government, and particularly our municipalities, to embark on new activities and large improvements has remained unchecked. In the administration of the affairs of government in our cities, states and federal service, the same spirit of progress and service are finding expressions.

With the increased demand for the prevention of social and economical depressions and for increase in the social, intellectual and industrial welfare of communities, the cost of government will unquestionably continue to increase. Increasing importance of these activities in the concentrated centers of population brings with it recogition that the government is a social agency and should perform all such services. This movement has steadily gone forward with decreasing opposition and protest of those who believe that the assumption of new functions and embarking on large improvements by government are unwarranted invasions of the field of private enterprise.

The increasing attitude of the public that government should have no limitations on the administration of those affairs which affect the industrial and social welfare of the people, is a most promising sign of the realization of ideals of democratic government and an indication of the position which the public is to hold in the future with respect to the public service. This tendency is positive and will be broadened more and more as the people become satisfied that governmental activities are performed effectively and honestly.

It would not be possible to enumerate and follow through all those functions which were once supposed to be peculiarly private in their character, but which are now exercised by government almost as a matter of course. It is difficult for us to think that the duty of

collecting taxes for the support of the state or the protection of life and property through police, fire and health departments are other than governmental functions and duties. Yet these functions, and others just as public in their nature, were once regarded as peculiarly sacred to private enterprise.

The following reference of the sources of wealth and political power of Crassus in 69 B. C. as chronicled by Ferrero, is interesting and amusing in this respect and can well be used where private enterprise objects to and opposes governmental administration of affairs which are peculiarly community affairs:

> "Since the houses at Rome were mostly built of wood, and the Aediles had so far failed to organize efficient measures of prevention, fires were at this time exceedingly frequent. This suggested to him a very ingenious idea. He organized a regular fire brigade from amongst his slaves and established watch stations in every part of Rome. As soon as a fire broke out the watch ran to give notice to the brigade. The firemen turned out, but accompanied by a representative of Crassus, who bought up, practically for nothing, the house which was on fire, and sometimes all the neighboring houses which happened to be threatened as well. The bargain once concluded, he had the fire put out and house rebuilt. In this way he secured possession of a large number of houses at a trifling cost, and became one of the largest landlords at Rome, both in houses and land, which he was then able, of course, to exchange; to sell; and to buy up again almost as he chose. Having become in this way one of the richest, if not the richest man in Rome, his power steadily increasing with every rise in the price of money, Crassus soon became a dominating figure in the Senate and the electorate, and indeed all classes of the community."

Within the past fifteen years and even more so during the last few years, the tendency for governmental administration and supervision of affairs which affect the economic and industrial condition of communities has been particularly manifest in our municipalities. This tendency has gone so far as to include a number of industrial activities and services, which were originally carried on by private organizations for profit. They have become so essentially public in their nature that the people have demanded that our municipalities undertake them and substitute increased service for the profits which private interprise was wont to make.

Our municipalities early began to take over sites for our public works and public property, our markets, docks, harbors, and parks and playgrounds. More recently, cities have been acquiring water supply systems, so that at the present time 155 of the 204 cities, having an estimated population of over 30,000, are reported as owning their water supply systems, the total estimated value of which is over $1,000,000,000. Similarly, our municipalities have gone into the business of supplying electrical current and lighting of streets and

the control or supervision of transportation facilities and of the other local public utilities. The city planning movement, which up to very recently had not been given the attention and study which the growth of cities demanded, gives promise of becoming one of our most important problems in municipal improvement.

Other activities which have been under municipal control for a number of years are increasing in their complexity and importance. The problem of efficient and economical administration must be solved by a personnel trained and prepared in the administration of these important and technical activities.

It would not be possible within the confines of this paper, to go into detail on the diversity and complexity of the problems confronting our municipalities, nor of their growing importance. A mention of some of the more important technical divisions indicates the field and broad opportunities and urgency for a trained personnel in the municipal service:

1. Finance administration and municipal accounting.
2. Taxation, budget making and municipal financing.
3. Municipal reports, publicity and statistics.
4. Technique of constructive investigation and reporting.
5. Civil service administration and standardization of employment.
6. Standardization and centralization of purchasing and testing.
7. Management and administrative procedure—scientific management.
8. Education administration.
9. Public health administration.
10. Justice, charity and correction administration.
11. Social surveys—Housing.
12. City planning.
13. Police and fire administration.
14. Public works administration and local improvements.
15. Water supply administration.
16. Municipal lighting.
17. Pavement construction and repair.
18. Cleaning of streets and removal of snow.
19. Sewerage systems and sewerage disposal.
20. Collection and disposal of city wastes.
21. Parks and play-grounds and recreation administration.
22. Elimination of smoke nuisances.
23. Regulation of local public utility rates and services.
24. Street railways, elevated roads and subways.

In our federal, state and county governments, the movement for democratic, social and economic administration has been similar, although not as intense as that in our municipalities. Problems of regulation of monopoly, conservation, stimulation of agriculture,

development of good roads and better transportation systems, regulation and control of public utilities, abolition of unfair privilege, democratization of credit, hours, wages, accident insurance, and employment,—these and other social and industrial problems and policies are before our people and public administrators.

The undertaking by government of activities, such as noted above, through the creation of administrative expert commissions, has a most important bearing on the future development of our public service and the ability to obtain effective and responsible results. The people have come to the realization that the evils and difficulties as they arise where a large number of people congregate, cannot be solved through legislation. This has come about through the inefficiency of legislation, through the inability of the ordinary courts to interpret doctrines in the new light and through technical, constitutional and legislative difficulties.

The experiences in cases of legislation and interpretation by the courts on the problem of regulation of monopolies and utilities have brought out the need of responsible expert administrative bodies. These have the advantage over our legislatures and our courts in that their opinions and actions are determined upon after thorough investigation and analysis of technical facts. The increase in the number of public utility commissions, valuation commissions and other bodies having to do with the regulation and control of public utility rates and services has brought about a great demand for experts prepared to go into this increasing division of the public service.

The staff of engineers and other experts assembled by the Interstate Commerce Commission in its work on the physical valuation of railroads is a notable example of newer opportunities and demands of the public service. Out of a total of over 18,000 applicants about 6,500 eligibles have been secured and somewhat more than 1,200 have been appointed during 1914 and 1915. Of the 46 distinct kinds of civil service examinations held, most of them were for technical positions of the highest order. Eighty-seven appointments have been made at $3,000 and $4,800 per year.

It is interesting to note in this connection that both the United States Civil Service Commission and the officials of the Interstate Commerce Commission have indicated their satisfaction on the high order of this engineering organization, which was obtained by competitive civil service examinations, and of the exceptionally efficient and satisfactory services which are being rendered by this most remarkable engineering staff engaged in the big task of making a physical valuation of all railroads in this country.

As has already been pointed out, the increased demands for service and growing complexity of the new undertakings have had direct effect on the attitude of the people toward the personnel assigned to administer these affairs. There has come about a demand for simplified organization and for responsive and efficient administration of public affairs. Where the demands for more effective and

responsive administration have been greatest, there has developed new forms of municipal government; the most important features of which are centralized administrative authority, the divorce of politics from administration and the employment of experts to administer the public affairs. With these there has also come greater freedom of municipal citizens in administering their local affairs. Progress along these lines has been phenomenal and today in a large number of our municipalities the transition is complete.

The destructive storm which overwhelmed the city of Galveston in 1900 has proved to be a great blessing in so far as the benefits which have accrued in a large number of our municipalities due to the departures from the federal plan of municipal government. Immediately after this catastrophe, the citizens of Galveston placed the problems of government of the city in the hands of a commission, which became the governing body of the city. This commission was made responsible to the people for the straightening out of financial, legislative and administrative affairs of the city.

The experiences and results obtained in Galveston under the commission plan have been such that within the short period of a decade, about 85 municipalities having a population of over 30,000 inhabitants and over 100 cities having a population of less than 30,000, have adopted and are now working under the commission form of government. The pamphlet recently issued by the United States Bureau of the Census contains figures showing the growth of the commission form of government and interesting financial statistics of some of the larger commission government cities. The 85 cities of over 30,000 inhabitants are scattered through 27 states; 5 of them are in the New England states; 30 in the Northern states, east of the Mississippi; 16 are in the Northern states between the Mississippi and the Pacific coast states; 9 are in the Pacific coast states and 25 are in the South. Of the 184 cities in this country having a population between 30,000 and 300,000 over 80 such cities with the total population of 6,480,000, or 45 per cent of the aggregate population of 184 cities are now operating under the commission form. Of the 195 cities having a population between 30,000 and 500,000 inhabitants, 85 cities with the population of 7,677,000, or 41 per cent of the aggregate population of these 195 cities are under the commission form of government.

Not content with the improvement and advances made in administration through the adoption of and operation under the commission form there has within the last two or three years been a further development in the municipal field. To further fix responsibility and provide centralized administrative authority, there has come into being the commission-city manager plan of municipal government. This form is similar to organizations which are found in our large private industrial and commercial corporations. The commissioners who are elected at large, who appoint the city manager and who are directly responsible to the people, correspond to the di-

rectors of the corporation. The city manager is an expert administrator and trained in technical public service problems and corresponds to the manager of the corporation. The electorate corresponds to the stockholders of the corporation.

Within the last two years over 80 of the municipalities in this country have adopted the city manager form and there seems to be no sign of abatement in this direction. These commission-manager cities are scattered through 28 states. Michigan, which has 9 city manager cities, is in the lead. California and Texas each have 8, and Virginia and Ohio each have 7 city manager municipalities. According to geographical divisions, the North Atlantic states have 8 city manager cities; the South Atlantic states 18; North Central states, 28; the South Central states 21, and the Western states 10.

Because of the short period during which the city manager form of municipal government has been operated, it is not possible to obtain comparable figures of the workings and results between the city manager and federal forms. From reports received from a number of the city manager cities and the expressed satisfaction of the people in these cities, there is no question that municipal administration under this businesslike form of organization is here to stay. Results which are being obtained in these cities are a recognition that the affairs of government, like those of private corporations, must be administered by a personnel, trained and expert and entirely divorced from the political, legislative or other divisions which are foreign to the big problem of furnishing effective and economical service.

Honorable Henry Waite, city manager of Dayton, which, by the way, is the largest city that has adopted the city manager plan of government, outlines the advantages of the city manager form of municipal government as follows:

(1) Simplicity.
(2) Basis of Organization—Efficiency and Economy.
(3) Centralized authority.
(4) Fixed definite responsibility.
(5) Business methods.
(6) Prompt and effective action.
(7) Employment of experts when needed.
(8) Commissoners represent the whole city, not ward.
(9) Interests a higher type of men in city service.
(10) The short, non-partisan ballot.
(11) Abolishes politics from the administration end of government.
(12) Separates the legislation from the administration.
(13) Does not depend on ballot to select trained men for particular functions of government.

It is of particular interest to note that of the larger number of city manager cities, recognition has been given to the qualifications

of the engineer in administering the complex municipal functions. I understand that in the larger number of these cities the city managers are engineers who have had experience and training in public administration.

I have dwelt at some length on the tendencies of government growth, on the demands of the people for new activities, on their increasing complexity and importance, on the extent and character of the public service and on the newer tendencies and opportunities in the administration. While I realize the importance of setting out a complete picture on these matters, no argument or further statements are necessary to show the field of opportunity and the necessity for a large supply of men and women who have training and experience and the right attitude in respect to the public service.

These problems of public service which are presented by the new order of things, are being recognized by a growing proportion of our people. This is shown by the new civic spirit which has arisen in our municipalities and the attitude of the increasing number to serve as watchful and informed citizens, or as agents to carry out the affairs of government in a way such as to raise the horizon of civic and community service.

The program laid out by the Society for the Promotion of Training for Public Service, the discussions and papers by educators and public administrators on social, economic and educational possibilities and the need of co-operation between the educational and public administrative bodies, are all positive indications of recognition of the opportunities in and need of public service preparedness.

The growth of and increase in the number of civic agencies and the increasing co-operation of these voluntary organizations with government and further indications of the realization of the informed and interested citizenship of the interdependence of governmental administration and the social, intellectual and industrial welfare of communities.

The field of public service, which is performed by these citizen agencies, has increased with the growth of the functions of government. Opportunities are not only offered for work in these organizations, but governmental officials have turned to them for men and women to fill official positions requiring training and experience of public administrative problems and the knowledge of the structure and operations of government. Increasing activities and co-operation of these civic agencies with governmental bodies is bound to create a further demand for trained workers in public administration. The more important organizations and associations, which have been developed and are active in this positive and growing field, are the following:

Ballot associations.
Boards of trade.
Bureaus of municipal research.
Chambers of commerce.

City clubs.
Civil service reform associations.
Commercial clubs.
Educational associations.
Foundations for special research.
Health associations.
Housing reform associations.
Industrial associations.
Juvenile associations.
Legal aid associations.
Legislative leagues.
Local improvement associations.
Merchants' associations.
Municipal leagues.
Real estate associations.
Recreation associations.
Tax associations.
Training schools for public service.

Opportunities in the civil service are increasing faster than the supply of men and women who are trained and interested in the public service. Steps must be taken for thorough and sustained practical preparation for public service administration. The creation of a larger supply of men and women, who are trained and are genuinely interested in public affairs and wish to find a career in the official life, will go very far towards stimulating further demand for experts. This, I believe, will largely solve our problem of efficient and responsible public administration. There have been a number of suggestions and programs set out for developing such a trained army of civil servants. In the adoption of the following steps, there lay the solution for preparedness and increased opportunities in our public service:

1. Publicity of public administration and of researches on government and public administration.
2. Extension of merit system and positive employment methods and control.
3. Practical training for public service in connection with our educational programs and with civil service administration.
4. Federal enactment for the promotion of public service training and distribution of federal appropriations amongst individual states and cities on uniform basis.
5. Co-operation between administrative departments of the federal government, states and cities and our state and other educational institutions, providing for practical training and field work in public service.
6. Encouragement of training of public service to teachers and compulsory instruction of principles of democracy and public administration to children and immigrants.
7. Recognition of public service as a profession of dignity, social prestige and permanence.

DISCUSSION.

President Grant: Mr. Jacobs gave us some rather startling figures. If I understood him right, there are something like 15,000 separate governments in the United States, about 230 of which have civil service?

Mr. Jacobs: Reports show that in 1910 there were in addition to the federal and the forty-eight state governments, over 15,000 separate governments, of which about 3,000 and 2,400 were county governments and municipalities respectively, having a population of 2,500 inhabitants or more and the remaining 10,000 political sub-divisions, each of which had a population of less than 2,500 inhabitants.

Only 12 out of the forty-eight states and about 250 of the 5,400 counties and cities having a population of over 2,500 inhabitants, have at least part of the public service under the civil service system. These, with about 61% of the 480,000 positions in the federal service, constitute all the public offices and positions which are at present filled after competitive examination. These figures show great possibilities for development of the merit system in this country and the increasing opportunities for trained men and women for careers in the administration of public affairs.

President Grant: It seems to me that the figures that Mr. Jacobs has given us, of the number of governments and the cost of them, are rather startling. Another point, which he did not bring out perhaps specifically, was the small percentage of the governments which have civil service, and the comparatively large number—that is, considering the age of civil service—which have city managers. Civil service is about a generation old now, and the other form, the city managers, is only a few years old, yet there are nearly as many governments in that form. It seems to me that there is a very marked tendency there that is well worth studying.

W. S. Lacher, ASSOC. W. S. E.: The speaker referred to the ignorance of a considerable proportion of the population as the reason for the slow growth of these movements. I doubt whether ignorance is the right word. Should not we rather say lethargy or indifference? Every four years our postal service suffers a set-back because it is necessary to teach an entirely new set of men how to run the post-offices. That state of affairs exists for only one reason, and that is that the people of this country do not care. I venture to say that in the average town in this country that the appointment of a new postmaster creates no feeling of disgust, or dissatisfaction, that such a state of affairs exists. Most of the people think that is entirely proper. It is taken for granted that this is the way our postmasters should be appointed; and if the man is on the right side he ought to have the job. It does not occur to 90 per cent of our population that specially trained men should be given those places. I mention post-offices because it is a most prominent example and represents a very large item in the payroll of our government service.

This attitude may be illustrated in another way. The speaker mentioned that the beginning of civil service in this country was in the year 1883. My impression was that it was earlier; that we owe civil service in United States government affairs largely to President Rutherford B. Hayes. Hayes killed himself politically and was branded as an ingrate largely from the fact that he did not feel that all the "patriots" should be given positions. The fact that only such a small proportion of our general governmental service is under any form of classification today results simply from indifference on the part of the people. We cannot expect any greater success until people can be brought to feel otherwise than they do at present.

O. P. Chamberlain, M. W. S. E.: I am not advised as to how the managers are appointed. Doesn't it go back to the political party in power? I mean to say, where they have a city manager, what assurance has he of his tenure in office? Isn't he dependent upon the political party that happens to be in power when he is appointed?

Mr. Jacobs: The commissioners are usually elected on a non-partisan ballot and are held accountable by the people for both legislative functions and the administration of municipal affairs. These commissioners appoint the city manager, and he is responsible to them only for results. The commissioners being responsible to the people for all activities and wishing to gain and retain popular approval, naturally try to obtain and keep men who are efficient managers and administrators.

Mr. Chamberlain: Then to have a successful city manager you really must get the people first to consent to a non-partisan government.

Mr. Jacobs: Absolutely.

Mr. Chamberlain: That same thing has occurred to me in regard to the commission form of government. There has been a great deal of talk about government by commission. It has always seemed to me that government by commission is good or bad depending on whether you appoint a good or bad commission. I have known a number of commissions that have been appointed and they have not done well at all. I know a case now where there is a commission form of government, with three commissioners, who are absolutely partisan. So the thing goes back to what I had in mind when I asked that question; it goes back really to educating the people to do away with partisan politics in municipal affairs. If you can by a movement of this kind induce the people to see that it is to their interest to have a business administration, regardless of politics, and induce them to elect a manager or a commission on a non-partisan basis, then you will get possibly, probably, an efficient management of your municipality. But the root of the whole thing is to eliminate partisan politics from municipal affairs.

Mr. Jacobs: Partisan politics has no place in municipal government and must not under any conditions be countenanced in the administration of public affairs. The one big advantage of the city manager form of government is that responsibility is definitely fixed

and authority centralized. You can easily place your hand on that responsible party and this is more than can be done under the federal form of municipal government.

J. W. Lowell, ASSOC. W. S. E.: Partisan politics is being removed from the Government service, without doubt and the civil service commissions are to be congratulated on their faithful efforts in behalf of the government employe. At best, however, the government's appreciation of faithful service rendered by its employees and its care and protection of them is far below that of large private industrial and service companies.

With reference to salaries, Mr. Jacobs has shown that the government's service cannot be criticized. The salaries are fair, but there are other things to be considered and of these I wish to say a word or two.

The care and protection of life and health of the employees is exceedingly important, not only to the welfare of the employees, but as a matter of efficiency. What has the government done along these lines? We all remember the collapse of Ford's Theatre building in Washington, D. C., some years ago and the killing and injuring thereby of many government employees. What was the cause of this disaster—nothing more nor less than the overloading of floors. Did the government do as well as any one of our industrial employers by their crippled employees and the families who were dependent on the earnings of those who were robbed of their usefulness, and those who died as a tribute to customary government carelessness and neglect? In the first place, adequate factory inspection would have avoided that great calamity, and second, if anything was done it was caused by the great amount of publicity occasioned.

More recently a woman employe of the United States Census office had her entire scalp torn away because her hair was caught in a machine wheel which should have been covered. I believe the woman is still alive, but a helpless, dependent cripple. Just sixty days after that deplorable accident that woman's name was stricken from the pay-roll and she received no indemnity, pension, nor aid of any sort from her employers. Congress refused to give any aid for fear of encouraging carelessness among employees. These are just two examples recalled at random to illustrate the results of the lack of adequate "safety first" inspection and the indifference of the government to the welfare of its employees.

The installation of a safety inspection system in the government service such as that maintained by the U. S. Steel Corporation and others, would, if unhampered, not only effect immediate economies, but would make many radical changes of great benefit to the health, life and satisfaction of every employe.

The government does not reward the faithful and loyal service of its employees as do commercial firms, because advancement above a certain level is often influenced by partisan politics and there is no provision for the pensioning of employees.

Last Christmas there were discharged from the post-office

service in Chicago several employees who had given their lives to the government service—men who had for years braved all kinds of weather to deliver mail to our doors—men who had grown old and were not strong enough to weather these storms any longer and carry the heavy sacks of mail on schedule time. This is one of the many examples, for every year many faithful and loyal employees who have grown old in the government service are reduced in salary or discharged. It is heart-breaking for a man, after working twenty or more years, to be compelled to be thrown out because he is getting old. It is pathetic that such conditions should exist in this, the richest of all nations, one that stands for humanity above all things else.

The government will not get nor keep the personnel that the private businesses get until it offers at least equal inducements, and I hope that those of us who know the actual conditions will, upon every occasion, help to awaken the public's interest in this matter and so assist the experts of the civil service commissions in their noble efforts toward better conditions of the government service.

W. G. Potter, M. W. S. E.: There are a number of towns which have had the commission form of government and gone back. I should like to know if Mr. Jacobs has any data as to the reason for their going back to the old form, and whether it is because of poor commissioners or something wrong in the commission law. I have two cases in mind. One is that of Huron, South Dakota, a town, I should imagine, of about five thousand. The other, I think, is the largest city in the country under the commission form of government—Denver,—which was under the commission form for several years. It has gone back in the last month to the aldermanic form and to the former Mayor. I would like to ask the speaker if he has any data as to the number of towns which have thus gone back from the commission form of government, and the reason for their doing that.

Mr. Jacobs: I have heard of three cities which have discarded the commission form of government and of these, two had originally adopted the commission form not as result of a charter change, but purely through ordinance enactment.

The situation in Denver, which last month discarded the commission form of government and adopted a charter amendment which gives practically all executive power to the mayor and creates a city council of nine members, is peculiar. I am informed that the commission government did not fail there because of short-comings of its own or on the part of the commissioners alone. A combination of conditions and circumstances were used to becloud the issue and the citizenry, largely uninformed or misinformed, seem to have preferred a return to the old form rather than fight for what ultimately would have brought them more responsive and effective government.

The results of administration in a number of cities which have adopted the commission or city manager forms of government seem

to be generally successful and point to greater possibilities. Relapses which may occur here and there are proof positive that whatever the form of government, the interest and active co-operation of the people must be kept alive to obtain and maintain good and efficient government.

In connection with what Mr. Grant said concerning the growth in number of city manager and commission cities during the last ten years and the relatively slower growth of the civil service movement, it is interesting to note the courses taken by each.

The civil service movement was largely the outgrowth of spoils politics and developed first in the federal government and in the larger municipal and state services. The city manager and commission form of government had its inception in the smaller cities, where the advantages and importance of a change could be more easily shown and where a change from the federal form of government was less difficult of accomplishment.

The necessity for civil service in smaller cities has not been brought out as clearly as in the larger cities, the cry for jobs has not been so great, and the opposition to turning over an entire administrative personnel is ofttimes sufficient to deter the most grasping spoilsman. In the larger municipalities and other governmental units, the cry for jobs is so great that recruiting and general control of employment through a civil service system is absolutely essential. It is here where the need for effective merit administration has been greatest. With the development of positive civil service administration in the larger cities and responsible and effective administrative methods in the smaller cities, there is likelihood of greater strides in the establishment of both by our governmental bodies.

President Grant: What is the largest city that has a commission form now?

Mr. Jacobs: Buffalo is the largest of the commission cities, and Dayton is the largest city manager city.

Mr. Chamberlain: I would like to ask Mr. Jacobs whether he considers the management of a city by a city manager a practical proposition in a city of the size of Chicago, for instance.

Mr. Jacobs: I think so. I think that a man who is expert and trained in the administration of public affairs would be better able to administer those affairs than a man who was appointed or elected on merely political basis, and has to turn his office over at the end of two or three or four years.

Mr. Chamberlain: In a city of this size, if you had a city manager would you insist on civil service there too? That is, would you assume that the city manager would come in and take charge of the organized departments which are now under civil service, or perhaps put all the departments under civil service?

Mr. Jacobs: I would place all the departments under civil service.

Mr. Potter: If you had a city manager in charge of a large city

I do not see how he could be held responsible for the entire work of the city if the subordinates were all under civil service. He could not be responsible, even with the best of civil service, for the work of all the employees of the city unless he could hire and discharge them without interference.

Mr. Jacobs: An executive who aims to obtain effective and economical administration and good service realizes the great help that a proper merit system can be to him, to the public and to the employees. The problem of correct employment methods is recognized in every large private institution. Positive employment systems based on merit are more necessary and work out better in the public service than they do in private services. The technical problems and the details involved in hiring and discharging, say from 5,000 to 30,000 employees, is so enormous and so involved that none but especially trained employment staffs can successfully cope with same. With the establishment of positive civil service administration, examination requirements and tasks, work specifications and duties are clearly defined, aid is given to the administrative officials in controlling and compensating employees according to service and efficiency and to the individual employe in having responsibility of supervision and accomplishment definitely fixed. With the divorce of politics from administration and the assurance of tenure, advancement and promotion on ability and service, a better and higher grade of personnel can be encouraged to enter the public service and remain there for a career.

N. M. Stineman, ASSOC. W. S. E.: I have in mind a certain man in this city who was appointed last winter to a position, which, under the ordinance creating the position, clearly belongs to a mechanical engineer. This man met what he supposed was the letter of the law by attending night school for a few months and getting a so-called stationary engineer's license. There seems to be a question as to whether he did meet the letter of the law, but he certainly did not meet the spirit of the law; and the point of information I would like to have is whether an individual or an organization would have the right to sue for an injunction against the City Comptroller, in an attempt to prevent him from paying this man's salary.

President Grant: That is a question of law. I don't know whether Mr. Jacobs wants to answer that or not.

Mr. Jacobs: I not only think that it is a right but it is a duty of any citizen or organization to go ahead and do that. I think that the average citizen or organization has not acted as they should on not only that violation of law but other violations of law. Just as soon as the officials realize that public opinion is eternally watching and will stop them from despoiling the service, violations of laws and ordinances will stop and conditions will improve.

President Grant: Is that position referred to a civil service position?

Mr. Jacobs: No, it is not, but the requirements are defined by a city ordinance.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

MECHANICAL DRAWING FOR COLLEGES AND UNIVERSITIES. By James D. Phillips, Professor of Drawing, University of Wisconsin, and Herbert D. Orth, Instructor in Drawing, University of Wisconsin. Scott, Foresman & Co., Chicago and New York, 1915. 275 pages, 6 inches by 9 inches.

As indicated in the title, this book is intended for university classes and it is understood that it is to be followed by a book for high schools, thus making a complete course in mechanical drawing for high school and university work. The authors have attempted to give the book both an educational and commercial value, to develop, as the authors state, the observation and perception and at the same time give the student an appreciation of the best commercial drafting room practice.

The contents of the book are as follows:

Chapter 1.—Perspective Sketching.
Chapter 2.—Orthographic Sketching.
Chapter 3.—Pencil Mechanical Drawing.
Chapter 4.—Tracing and Blueprinting.
Chapter 5.—Instruments and Materials.
Chapter 6.—Conventions.
Chapter 7.—Lettering.
Chapter 8.—Advanced Drawing.
Chapter 9.—Auxiliary Views, Isometric and Cabinet Drawing, Tables, etc.
Chapter 10.—Instructor's Guide.
Outline of Course in Mechanical Drawing.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Meeting No. 940, June 5, 1916.

The meeting was called to order about 7:50 P. M. by President Grant, with about 40 members and guests present. The Secretary reported from the Board of Direction that the following had been elected to membership in the grades specified:

Horace D. Kerr, Chicago, Ill., Associate Member.

Robert L. Fitzgerald, Winnetka, Ill., Associate Member.

Henry C. Morrison, St. Louis, Mo., Affiliated Member.

Clarence M. Fuller, Chicago, transfer, Student to Associate Member.

James S. Harvey, Jr., Chicago, transfer, Junior to Associate Member.

James E. Cahill, Chicago, transfer, Associate to Member, and that the following new applications had been received:

Robert L. Lewis, Batavia, Ill.

The speaker of the evening, Mr. J. L. Jacobs, was then introduced, who presented his paper on "Public Service Opportunity and Preparedness." Discussion followed by Messrs. W. W. DeBerard, B. E. Grant, W. S. Lacher, O. P. Chamberlain, J. W. Lowell, Jr., W. G. Potter and N. M. Stineman. The meeting adjourned at 9:50 P. M.

Meeting No. 941, June 12, 1916.

The meeting was called to order at 7:50 P. M. by Chairman Lacher of the Bridge and Structural Section, with Chairman Lacher presiding, and about 75 members and guests present. Mr. J. W. Lowell gave a short description of the demolition of a reinforced concrete storage bin, built by the Universal Portland Cement Company at South Chicago. This was illustrated by a few lantern slides and a reel of moving pictures, showing the work of demolition.

The Chairman then introduced the speaker of the evening, Mr. Fred Ruchti, M. W. S. E., who presented his paper on "Comparative Designs of Office Buildings," which was profusely illustrated by lantern slides. The meeting adjourned at 10 P. M.

E. N. LAYFIELD,
Secretary.

ENGINEERS' DIVISION CHICAGO PREPAREDNESS PARADE

The engineers were very much in evidence in the Chicago Preparedness Parade on June 3rd, having about 2,300 men in line. They were led by Wharton Clay, Marshal of the Engineers' Division, assisted by Lieut. H. S. Baker, B. F. Affleck and E. H. Lee as aides. The arrangements for the Engineers' Division were made by a volunteer committee with the following officers: Chairman, Edmund T. Perkins; Vice-Chairman, Wharton Clay; Finance Committee, B. F. Affleck; Secretary-Treasurer, E. N. Layfield.

The participants in the parade contributed to the necessary expenses, the receipts and expenditures being as follows:

RECEIPTS.

Total contributions by participants in the parade and other engineers..$745.00

EXPENDITURES.

Bands	$342.00	
Flags, delivered	53.77	
Advertising in newspapers	115.43	
Printing	83.65	
Addressing notices, etc.	3.00	
Postage	81.55	
Messenger service, and incidentals	6.60	
Total		$686.00
Surplus		$ 59.00

The surplus, being too small to be returned pro rata to the contributors, will be disposed of in some manner to be determined by the committee for the benefit of the engineers.

Journal of the Western Society of Engineers

Vol. XXI. SEPTEMBER, 1916 No. 7

THE OPERATING MACHINERY OF THE WILLAMETTE RIVER DRAWBRIDGE, NEAR PORTLAND, OREGON

By Byron B. Carter.

Presented May 8, 1916.

DESCRIPTION AND CRITICISM OF THE PLANT.

The writer has had few chances of examining his work after a service of sufficient time to develop any faults. A short time ago he was pleased with the chance of making a critical examination of the mechanical and electrical equipment of the Willamette Draw after a continuous service of six years. A description of the results of this examination may be of interest to your members.

As the equipment has never been described so far as the writer knows, it seems advisable to couple the description to the criticism.

The Willamette draw is the largest of three on a line of bridges running from the east side of the Columbia River at Vancouver, Washington, to the west side of the Willamette River a few miles below Portland, Oregon. These directions are only relative to general geography and not to the local conditions.

A description of these bridges was published in 1910 by Mr. Ralph Modjeski, Chief Engineer, in his report to Mr. Elliott and Mr. Stevens, under the title of "The Vancouver-Portland Bridges." In this report the description of the operating equipment of all the draws is only general in character.

The writer was appointed Mechanical Engineer for all the bridges by Mr. Modjeski, and had charge of the design, fabrication and installation of all the equipments. The Willamette, being the most complete and heaviest equipment, is selected for description, but reference will be made to the others, especially the Vancouver or Columbia River crossing.

The Willamette draw span is 521 ft. 0 in. center to center end floor beams or 524 ft. 2 in. over all in length. The width is 31 ft. 0 in. center to center, trusses. The height at the center is 109 ft. above the masonry. The drum is 42 ft. 3½ in. diameter at the center. The

total weight on the center pier including all steel is about 4,600,000 lbs. Of this about 400,000 lbs. was classed as machinery and includes the drum, bearings, etc. This is the part to be treated in this paper.

Because the draw as proposed was then the longest, one of the heaviest, and by far the fastest operated in the world, the design of the equipment required the best possible preparation. There were no precedents, and such data for calculations as could be found did not seem reliable.

As this bridge was across the main channel for all ocean shipping to Portland, the demand was that the bridge should open in not more than three minutes from the start of unlocking to the full opening of ninety degrees. Allowing fifteen seconds for the rail locks, forty-five seconds for the end lifts and fifteen seconds for the operator between operating the different controllers, etc., this allowed one and three-quarters minutes for the swing from start to stop.

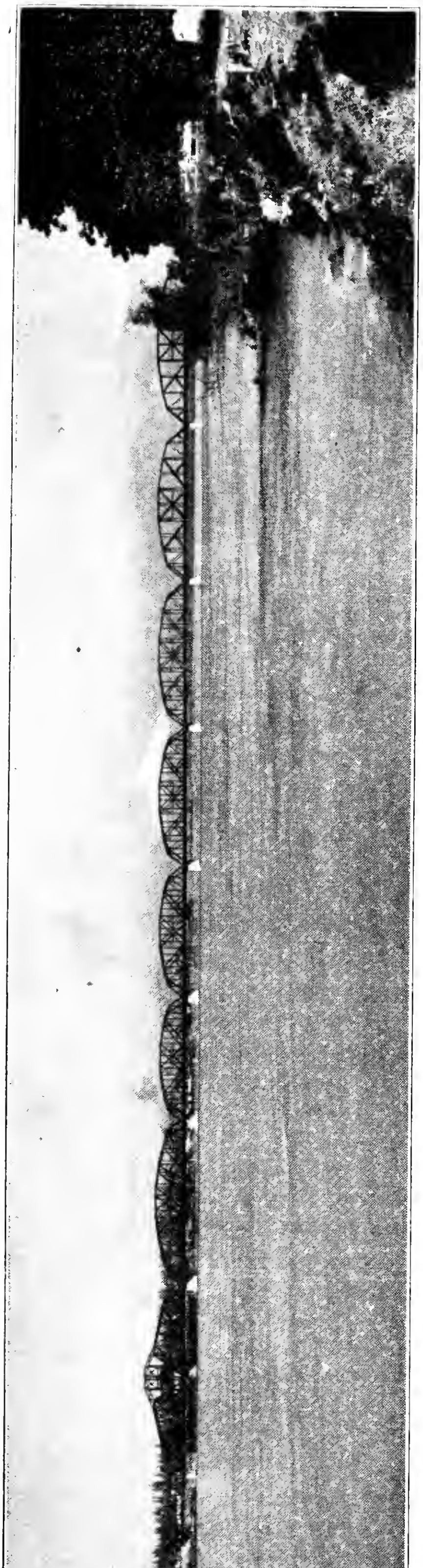
In order to get some basis for calculating the friction and accelerative requirements, a set of observations were made at the electrically operated draw bridge at Rock Island, Ill. These, though taken in a crude manner, gave results that seemed far more reasonable than the data available, and were used as the basis for all calculations.

The first part that we will consider is the drum and center parts. Although these are chiefly structural work, the writer was directed to assist in the design, and in criticising these will be criticising himself. As shown on Plate I, the span rests on a series of loading girders which in turn rest on twelve radial struts in such a manner that five-sixths of the weight is carried by the drum and one-sixth by the center. This is done by true lever connections, making the distribution definite. The drum is carried by sixty-six rollers, which will be taken up for description later. In this cut your attention is called to the relation of the main rack to the lower tread bearing. This shows the vertical section and how provisions are made for free drainage under the rack, a detail description of the connections here will be made later.

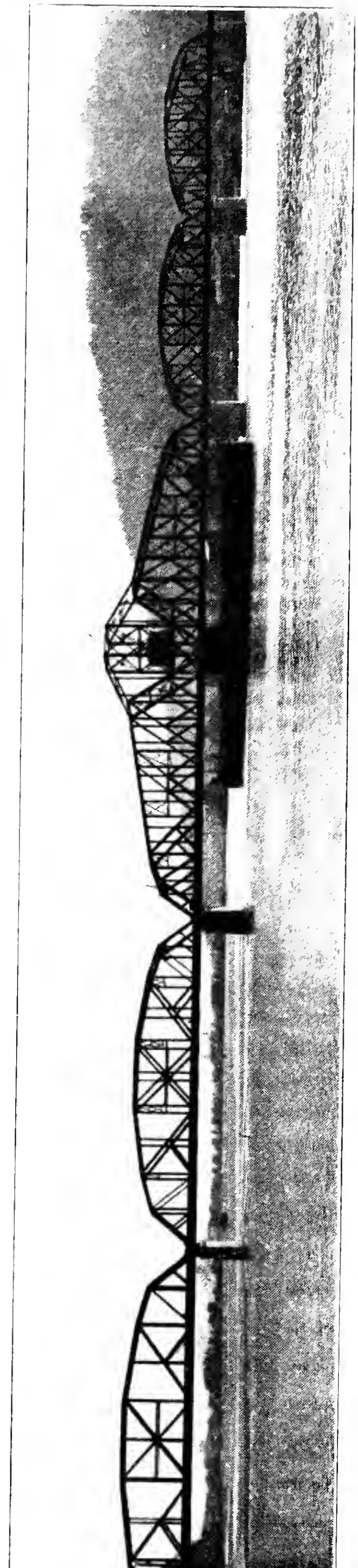
This view discloses clearly the connection of the roller circle to the center.

The rollers are each on a bolt shaft which is connected to a stiff circular ring.

This ring is composed of two bent channels spaced by a circular plate and angle diaphragm, and stiffened by lacing on the top and bottom flanges of the channels. This is an excellent construction and proved very stiff. However, the circular diaphragm seems unnecessarily expensive. I believe a small channel strut at each bolt would be sufficient. The bolts are pulled up tight and fixed by keys in the circular ring, the overhang extension passing through the rollers to the adjustment on the outer ends. The hole in the rollers is babbitted for two reasons: First, low friction and non-rusting bearing is thus produced, and second, although considerable babbitt



Vancouver



Willamette
Fig. 1

is required, in the end it is far cheaper to babbitt and bore at the required center than to bore in the rough cored hole in the steel, which is usually out of center with the best center for the outside finishing.

You will notice that there are no thrust washers on the inside end of the roller hubs, and there should be none. There can be no possible cause for the rollers to work towards the center. An opening of about one-fourth inch was allowed here.

On the outer end is a bronze washer thrusting to a thick steel washer, which is adjustably held by the lock nuts. The steel washer passes through and is feather keyed in the outside circular ring.

In this construction there is no thrust to the outside ring, but each bolt carries its own roller thrust and each roller is individually adjustable to true bearing. Instead of the double nuts shown, castle nuts and pins would have been better, although at that time they were not in common use.

The outer ring was connected to the inner circular girder by plates at intervals passing between the rollers and riveted above and below. This is not a good construction and is unnecessary. It makes a difficult and expensive location of parts to get all three holes in the true radial line and which, even though properly made in the shop, is very liable to be disturbed in the field riveting. There being no thrust or load of any kind on this ring it should be light, used only as a spacer between the bolt shafts and be kept parallel to the circular girder by connections bearing against the inside of the outer ring. The roller circle is thus not disturbed by any field work and is allowed to find the true radial position of all the rollers.

The circular girder is connected to the center ring by eleven stiff struts, arranged radially. The center ring is a steel casting with a large bearing to a cast iron sleeve ring centered and resting on the turned edges of the ribs of the center casting. This is a good construction, except that the struts have an excess of vertical stiffness, although perhaps not too much, as radial struts when considered under compression. It is a question, however, whether there is any compression in them. The weight of the circular girder, outer ring, and a large part of the radials is of course carried by the shaft bolts in the rollers. It was noticed when the bridge was swung that the center ring moved with a jerky action, indicating that the radial struts were too elastic horizontally. It would seem to require some tangential connection from the circular girder to the center ring. The large bearing of the center ring to the center casting proved a good feature, as it is easily oiled and kept in good condition.

In the center casting will be noticed a peculiar shaped figure, which indicates the hole through which the wires were brought for the electrical main power lines from a submarine cable.

Plate II is a design drawing of the drum of the Willamette Draw with interpolations of the main pinion connections of the Vancouver Draw. This interpolation is done so that both designs

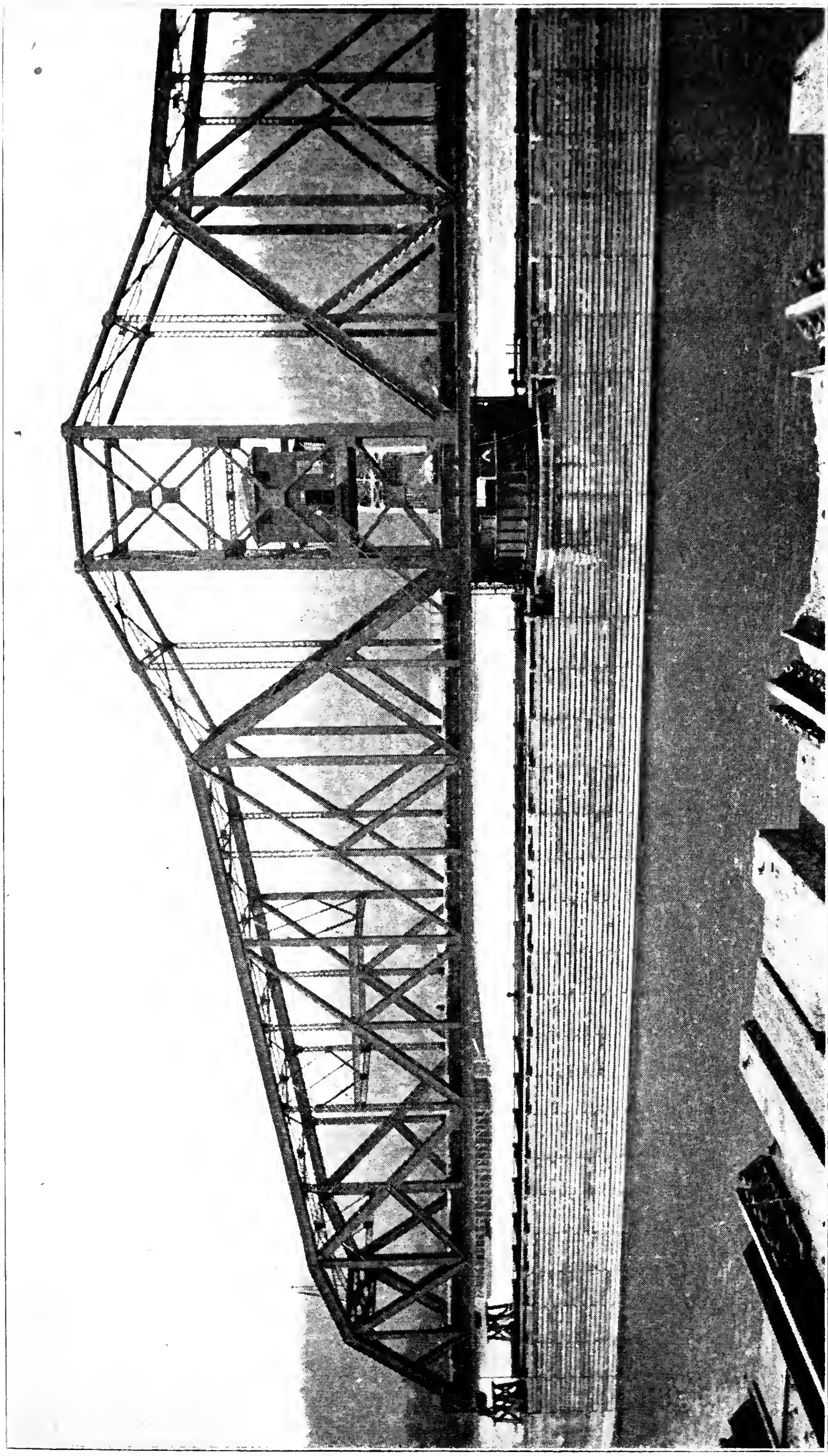


Fig. 2

may be before you at the same time, as it seems important to critically consider this very vital part.

Before going further your attention is called to the two diagrams at the lower right hand corner. The upper one shows the truss supports at eight points L, B, C, on top of the distributing girders L, B, R, & L. These in turn rest on the radial girders R, B, R, L, & I, arranged in twelve equal spaces around the drum. The distribution is such that one-eighth of the load of the trusses is equally distributed to three radial beams and to the drum.

The lower diagram shows the radial beams. The loading girders rest on each radial at a point one-sixth of the distance from the drum to the center, equally distributed to each. Thus is seen, as before stated, that five-sixths of the load is equally distributed to the drum, and one-sixth to the center.

It is stated above that the main pinion connection to the drum is vital. The writer fully believes this is true and that too often it is not properly considered; further, that many rack breakages could be traced to looseness or twisting of this connection causing illegitimate stresses on the rack and not due to weakness of the rack itself.

The structural details of both designs are fairly clear. In both the bottom gusset forming the bottom cover plate for a portion of the drum is firmly riveted. This construction is practically imperative. The chief and what seems to be the vital difference is in the bracket itself. The Willamette has three diaphragms while the Vancouver has but one. The outside angles of both extend the full length of the bracket. Those of the Willamette are bent and are attached directly to the top flange of the drum by the diaphragm connections. This bending seems in some way to stiffen them very much. Further, the bottom gusset is noticed to pass the two vertical angles of the center diaphragm. This seems the most vital, as stiffening the lower overhung portion, it would be even better to notch enough to pass the plate outside of the drum flange. This over-hang seems to be the weak spot. In the Vancouver brackets the rivets have loosened in the angles on the outer edge of the bottom gussets where they pass the vertical portion of the bracket and cracks are showing from some of the top rows of rivets. The Willamette is absolutely tight, the paint around the rivets not even disturbed, although this bridge has operated far more frequently and the loads on the brackets are much heavier. The Willamette design is very good, but it would seem that even this could be improved materially.

This drawing also shows the girder attached to the drum, to which the lower bearings of the machinery gear trains were attached.

The rack is in twenty-four sections of eleven teeth each. The pitch is 6 15/32, face 12″, pitch diameter 45 ft. 4 25/32″ as designed. As is seen, the stiffening rib is near the middle of the face of the teeth with four holding bolts to each rack section. On the lower bearing pedestal the rack bolts alternate with an equal number of foundation bolts. Each rib in the pedestal is extended to a raised

boss above the lower plate of the pedestal. At this point also a pad outside of the tread circle is turned off to fit a similar bored pad on the rib of the rack. In this manner the rack is made and fastened truly central with the tread at the shop. At each alternate pad is a key holding the rack to the pedestal against the tangential force on the racks. See Plate III.

As designed and as installed at Vancouver the rack is fastened down to the pedestal by 1½" cap screws threaded into the bosses. However, before the Willamette rack was attached at the shop, reports were received that the Vancouver rack was shifting back and forth at each operation. Although this seemed impossible, and as it was too far away for an investigation of the reason to be made, it was decided to make the holding bolts for the Willamette rack, as studs enlarged where passing the rack flange and fitted tight into reamed holes in the rack. This was a very expensive fix but was certainly sure, as besides all the keys, all the bolts resisted the thrust on the rack by sheer.

At the next trip to the bridges, and after the shop work for the Willamette was all done, it was discovered that the keys at the Vancouver bridge had been made 1/32" smaller than the key-ways and that any one could be picked out by the fingers. New keys were made to be driven in, and the shifting of the Vancouver rack stopped for all time. Thus we see that an entirely unnecessary expense was caused by the habit our friends in the bridge shops have of making a fit by allowing a clearance. We were even told it could not be done any other way. But it was done easily, and entirely cured our troubles. The rack sections are bolted together at the ends in the usual manner, but with only 1½" bolt at the joint, which has proved to be ample.

In general this rack attachment has proved to be very good, but does not need the fitted holding bolts. The relation of the live circular girder, outer ring thrust collars and roller, are all shown in larger scale and clearer than in the previous view.

The rollers are cast steel turned to the true cone, and the threads on both the drum and pedestal are forged steel turned to the cones in place. This is the usual good construction and has proved good in service. Further comment does not seem necessary, except that examination after six years of service shows practically no wear, as there are no indications of any wear ridges on the treads which overlap the rollers all around.

We next come to the center. As far as the writer knows, several features are shown here that have not been used before in similar cases. The lower, fixed main casting, is of the usual ribbed design with top and bottom plates. The bottom is rough finished to straighten the surface and assure a good bearing on the masonry. The top plate is smooth turned to two elevations; the center, one inch high and twenty-seven inches in diameter, is the base and centering of the bearing lenses. These consist of three parts all 27

inches in diameter, two single concave lenses of forged steel, the curved faces polish finished to 12-foot radius and one double convex lense both faces polish finished at 11 ft. 11″ rad. This lense is of cast "Lumen" metal, a product which is about 80% zinc. The lower steel lense is flat on the bottom, while the upper has a ⅜″ high extension 5″ in diameter fitting into a recess 5″ diameter, ½″ deep, in the upper casting on which and to which the drum radials rest and are bolted.

The outer or retaining ring is made in halves, securely bolted together on leather packed joints. This is 27″ inside diameter, fitting the extension on the lower casting and bolted to the lower casting with 2¼″ bolts. The outer part of the upper casting is turned 1/16″ small. At the top of the retaining ring is a cupped leather packing and outside this is a drain and dust shield. The design is such that the retaining ring brings all parts into accurate center, and yet by removing this ring in halves and jacking up the top casting ½″ the center lenses can be removed for repair or replacement. The oil is piped into the central hole in the top casting, the pipe carried up to the top of the radial girders and a hand oil pump capable of producing 2,000 lbs. per square inch is attached to the top of the pipe. An oil hole is drilled through both the top steel lense and the Lumen lense, the latter having radial oil grooves. But the bottom steel lense was not drilled. Thus the oil is free to go over both surfaces of the middle lense and must go over at least one to the outside. By use of the pump, oil can be forced to pass one or both surfaces.

Lower down in the top casting you will note another tapped hole and drilled connection to the outside of the lenses. In this is a pipe, "goose necked" at the top. It was intended that the cupped leather packing should form a hydraulic cylinder of the retaining ring, which would lift the center by applying pressure at the pump and thus flood the lenses, the oil to drain from the return pipe above. It failed—the packing does not hold and the oil runs over the top of the retaining ring. But this ring thus forms a cup holding oil. The force pump is not necessary, for, after six years, on pouring oil into the central pipe it runs out freely at the top of the ring. This is probably due to the fact that the lense faces do not fit; they were made not to fit by being of different radii. There seems absolutely no logical reason why they should not be made to fit in the first place and should be made so. The oil grooves to be stopped at about ½″ from the outer edge. There seems also to be no reason why there should be three lenses. One concave and one convex of different metals will give all the desired results of the three, would be cheaper and better. One should be key fastened to the lower casting, the other key attached to the upper. This bearing has given no trouble of any kind. It works smoothly and a close examination gives no indication of much wear. The pressure under operation was intended to be about 1,200 lbs. per square inch over the whole surface, but the actual pressure must be some higher, as it seems

probable that the full surfaces do not bear as stated above. At the time of observation, there was no opportunity to remove the lenses, owing to river and railroad traffic. It would have taken several hours, hence the actual conditions are not known.

As said earlier, the operating requirements were very severe, and as there would be very little opportunity for repairs it was decided to make all parts so strong that breakages would be unlikely. Further, each gear train to be so designed that any two main pinions and trains would be able to operate the bridge except for the extreme possible conditions. See Fig. 3.

The main pier is but 50 ft. square at the top and as the drum is so large, it was found impractical to arrange the machinery at the

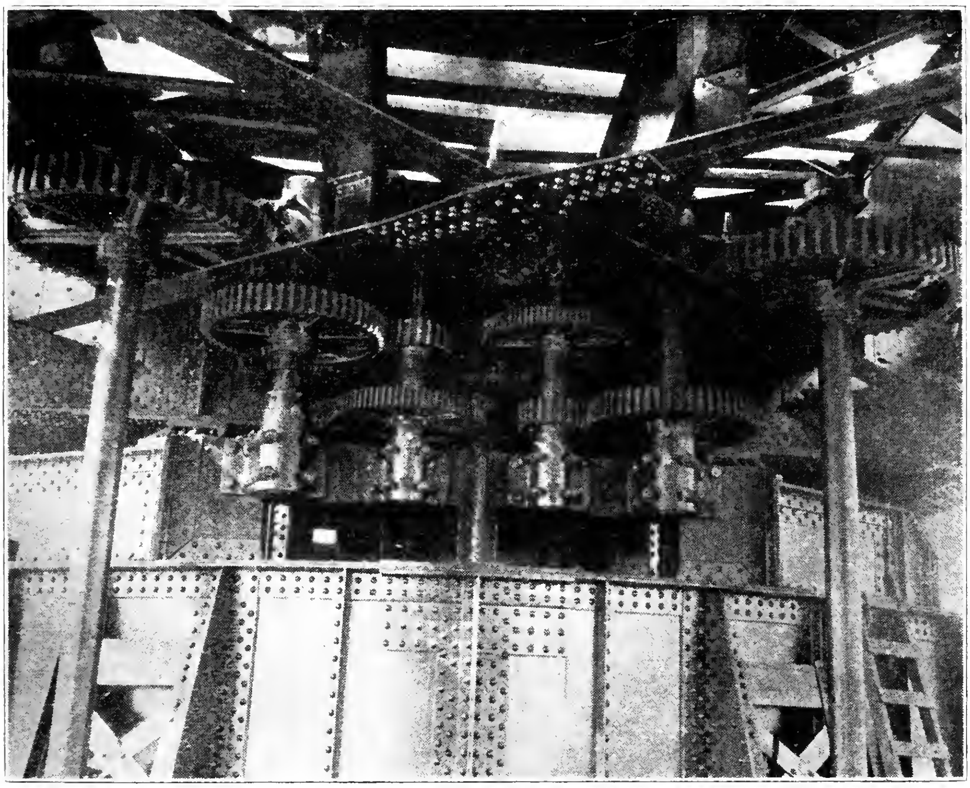


Fig. 3

sides of the trusses. This was the arrangement at Vancouver—cut. In all such arrangements attempted some part would extend into the channel opening when the bridge was open. The loading girder square above the drum was so stressed that any piercing for shafts could not be done.

As finally located, the machinery is in two trains equalized to two pinions at each side of the drum under the deck. The large gears at the top of the main pinion shafts are above the members of the bottom lateral system and hence above the low iron clearance of the channel opening for the closed position.

The other gears and shafts arranged vertically are set back within the pier line. See Plate IV. From the bevel gear equalizer a bevel pinion is set below the gear on a shaft whose bearing is attached to the lower flange of the cross loading girder. On this last shaft is a brake wheel and back gearing to the motor. The motor is spring suspended on the shaft, inside and above the drum. All of the top bearings of the gear trains are attached to box girder struts between the deck stringers, while the lower bearings are all attached to the girder on the drum previously mentioned.

The arrangement of all parts is such that any shaft and its gears are independently and quickly removable. However, to date there has been no necessity of removing any except as stated later.

As the machinery is duplicated at each side of the drum, there are four pinions in action during the swing. The motors are connected in parallel to two controllers so that there is full equalization between the pinions. The motors are each rated at 75 horse-power at about 500 R. P. M., but were designed and proved by test to produce a torque more than three times the rated torque. They are speed controlled by resistance in the secondary currents.

To give a little idea of the size of the parts (the pitch of the rack was given previously), the main pinion shaft in the pinion and lower bearing is 10¾″ dia., 9″ dia. above and in the top bearing and gear, and is 18 ft. 8 1/16″ long over all. The gear at the top is 3⅞″ pitch, 9″ face, 5 ft. 7.84″ pitch dia., and weighs about two tons.

The weight of all the shafts is carried by thrust collars on the lower bearings only. There is a clearance of about ¼″ between the gears and bearings at the top.

This machinery was erected by a bridge erecting crew and could hardly have been put in worse. Before being finally put in service, it was gone over again and nearly every bearing had to be moved. Some of the bearings were ⅛″ out of line in their own length. The gears were properly located as to pitch bearing, but the bearing boxes which were erected with the shafts had evidently been shifted because not securely clamped in drilling the bolt holes in the steel. It was intended that all holding bolts should fit tight in both the steel and bearings. In moving them the holes had to be chipped out, but by blocking in the holes the bearings were well secured, but at considerable unnecessary expense. Hardly a single shaft was found properly aligned. Only one shaft in each train has required removing since. For some unexplained reason the thrust bearings on the equalizer shafts wore rapidly, probably from poor lubrication. New ones were put in, requiring, of course, the removal of the shafts. The new bearings are giving good service. The examination of these gear trains disclosed no defects of any kind. The wear of the gear teeth was very slight and quite equal over all the gears. Some of the original roughness of the cast teeth was not entirely removed and none of the bearings had required

taking up. In the design, efforts were made to equalize the fiber stresses in all parts and also to equalize the bearing pressure on all the teeth and bearings. The examination indicated that this had been secured.

The first winter after the bridge was put in commission the region was visited by one of the worst sleet storms and cold waves ever experienced. Sleet formed on the rollers and on the lower tread where each was exposed about ¼″ thick. In attempting to swing it was found that the ice did not crush, and hence the bridge had to be lifted at each spot of ice. The engine also got out of order for full power production, as will be explained later. The result was that tugs had to be secured to help swing until the ice melted. Electrical difficulties developed, as will be stated later, and all combined, caused great uneasiness of the railroad management. To prevent similar troubles in the future it was decided to make some changes in the machinery.

As before stated, provisions were made to swing in 1¾ minutes, but after the machinery was smoothed up and extra friction removed, it was found that the acceleration was faster than expected and that the swing could be made in 1¼ minutes when full power was available.

It was found that the speed of swing attained was not necessary, as a slower swing could easily keep away from boats operating as fast as they ever did at that point. So new back gearing from the motor to the suspending shaft was installed, reducing the speed about one-third, and increasing the effect of the motors. In addition, in order to have two motors always available, a third motor like the other two was installed and so arranged by slip pinions that it could be coupled to either train through the back gears on the suspending shaft. This motor was not spring suspended, but is attached to the radial girders of the drum. A short three-wire cable with clip ends serves to couple this motor into either set of motor electrical connections. Since being installed and the connections tested, it is stated that the auxiliary motor has never been put in actual use.

Each brake is of the band form lined with vulcanized fiber and operated by an air cylinder. The two cylinders are connected to one brake valve of the locomotive type and are operated by direct compressed air at about 80 lbs. It is found that the motion of the bridge can be controlled with ease and definiteness, yet when fully set the brakes will hold against any conditions that have as yet developed. The brakes were calculated to have an effect 1½ times the over-load rating of the motors, but to slip at a point producing stresses well below the elastic limit of all the gears, etc. There is not much to criticise in this machinery except as has been stated above.

The end reactions at both the Vancouver and Willamette bridges were estimated to be about the same, so it was decided to make the end lifting mechanisms the same for both bridges. See Plate V. The

requirements at the Willamette were that at each corner or lift a load of 225,000 lbs. was to be lifted 1½″ in 45 sec. and the devices were to carry a total load of 720,000 lbs. Deformation calculations disclosed considerable endwise movements under the action of the live loads provided for. Considerations of all the known forms of end lifts disclosed defects in each, either lack of bearing values under the above loads, lack of efficiency, or tendencies of producing thrusts on the masonry from end movements, due to the live loads, that could not be permitted, especially at Willamette, with its high and slender piers.

To overcome all the above defects a design was developed that is supposed to be a new form of end lift. To adapt the truss to the lift, the end pin connection was omitted. The connection is riveted into two main gussets at each side of the chord. In these gussets are placed 12″ pins, near the top of the connection and outside of the end posts, that carry the end lift reactions only. These pins, which are removable, are held in by plates bolted to the gussets and are prevented from rotating by bolts, through the plates, tapped into the ends of the pins.

Each end lift consists of two cast steel toggle struts, eleven feet long from end to end pins. The top joint is bushed with Lumen bushings to the pins in the gussets. The other joints are finished cylindrical surfaces of the castings 11″ rad., 20½″ face, on babbitted surfaces, one in the upper end of the lower strut and one in the lower bearing shoe. Five-inch pins are used here to join the parts and carry the weights only when the jacks are lifted, but they carry none of the loads when the ends are raised. The lower bearing shoe slides vertically about 7″ in guides, bolted to the lower extensions of the gussets. The lower bearing shoe rests on 6 segmental rollers 12″ dia., of the usual expansion joint form, except that they are gear tooth connected to the pedestals and are arranged with pendulum weights to keep the rollers in the vertical position when the end lifts are released. In this manner the great efficiency of a toggle action is combined with a construction of large bearing surfaces and perfect freedom of end motion allowed on a free moving roller expansion bearing.

The centering and latching of the bridge is produced by a plug with tapering ends, attached to the lower member of the toggles, working in a socket which is attached to the chord of the approach span.

The relations of the plug and socket to the end lift are such that the parallel portion of the plug has entered the socket and aligned the bridge before the lower shoe takes bearing. The taper centers from about 5″ each side of the bridge center line.

In the upper toggle links are independent pins with bronze bushings for the strut connections. The toggles are actuated by cranks and cross connecting shafts between the trusses. The bearings for the shafts are attached to the top of the lower chords.

Connecting the cranks to the toggles are struts made of structural steel and steel forgings. Mounted on the cross shafts are heavy segmental gears, which are driven by 35 H. P. motor through a single gear train for each end of the bridge. It is thus clear that both sets of toggles for one end of the bridge must act simultaneously, while the ends are independent of each other. The synchronous speed of the motors is depended upon to get practically simultaneous action at the ends and does so within one or two seconds.

The drawings show all parts in the locked position, that is, with the ends lifted, and it is seen that the unbalanced weight of the segmental gear holds all parts in position. The gear train is mounted on a structural framework attached to the two middle stringers at the end panel of the bridge. The cross shaft pierces, but is not supported by, all the stringers at their central and neutral axes.

The shafts of the gear train are not on one line, but are zigzag with each other, so that shifting, either horizontally or in height, could be done to accommodate the actual diameters of the gear castings.

Across the framing back of the segmental gear, and bolted to the framing is a heavy timber bumping block, not shown on the drawings, to prevent an over-travel of the segmental gear. The device was erected first in the Vancouver draw and used during the erection of the fixed spans before the bridge was put in the railroad's service. It soon developed that the friction of the gear train was not sufficient to overcome the out of balance condition of the segment gear for the unlocked position, although the moment was small, and any impetus given to the machinery would cause the train to run back to the locked position when the bridge was open. This was, of course, a bad error. To overcome this, a lever about five feet long was mounted on the cross shaft at each side near the chord. At the ends of these levers heavy weights were suspended by links and the positions of all are such that for the locked position the weights have practically no moment, while for the unlocked position the moment is the full length of the arm. There is no drawing of this scheme to show, which is unfortunate, as it entirely and permanently cured the trouble.

The stopping of the machinery at the limits of travel is produced automatically in a drum controller operated with quick action at the ends, by a gear and idle space device mounted on the cross shaft. At the time the machinery was designed, solenoid brakes had not given very good results, and those suitable in three-phase work did not appear very reliable. So it was decided to avoid using them. The stop is produced by reversing the motors through resistance and by a fly-ball governor opening the circuit breaker in the lines supplying the motor at the instant the motor stops. Considerable experimenting had to be done to find out the proper amount of resistance to use, which also had to be changed as the friction of the train was reduced,

but when finally adjusted the stops are perfect and have continued so. During the experimenting some of the struts were bent from over-travel as the bumping blocks would be torn out, and a tooth from each of two pinions was broken by the segmental gears running out of mesh and then hammering back.

The automatic stop drum and wiring is very complicated. With present practice in solenoid brake construction as developed on cranes, all the troubles stated above can be avoided and now would be the best practice, although care should be taken to protect the brakes from water or undue dampness. A hand operating mechanism is provided by fitting, removably, a large wheel with six handles on one end of the rotor shaft of the motor. This is very slow, requiring about 5 minutes to lock or unlock, but is effective. However, the only time the hand connection was ever used was during the adjusting of the stops at the Willamette bridge. We were caught several times in a condition inoperative by power by boats requiring a swing.

The entire machinery in the middle of the bridge is roofed over water-tight and there is a floor resting on the bottom flange of the stringers. Access is obtained through a trap door on the railroad deck.

The examination disclosed some interesting conditions. There was ample evidence that the roller bearings had operated under live load actions of the bridge. It was reported that a movement of 3/8″ had been measured during the movement by one of the operators who had been in position to observe it when an unusually heavy load was crossing the bridge. The writer observed and measured a 3/16″ movement under the load of a heavy locomotive preceded by a car of rails and two of ties.

Service has developed a situation not anticipated. Some of the connecting pins between the lower toggles and the shoes, which were not fastened in, were working endwise and rubbing hard against the gussets. They should have been held by screw keys.

The connecting pins at the middle joints, which are fastened by set screws, are tight.

But in one lift there was found a very curious and surprising condition, that would be a good subject for a discussion of fraction and lubrication.

A top pin, which, as stated before, is bushed with a lumen bushing and held to the gusset from turning by bolts tapped into the pin, has had developed between the bushing and pin sufficient friction to sheer off the dowel bolts and was turned in the gussets. The pin did not seem to be seized in the bushing, as it was reported that it frequently turned in the bushing. There is no provision for lubricating the bearing in the gussets, while good provisions are made for lubricating the bushing.

The bearing load per square inch is, of course, very much higher between the steel and the pin, and the bearing surfaces much inferior

as to anti-friction conditions. The question is, why does the pin turn there? The cure, of course, is to fasten the pin with a large screw key, and in future designs to make a more secure fastening. In only one pin of eight on two bridges has this condition developed.

Some of the spent grease was taken from one of the tight pins and analyzed, which showed about an equal amount of zinc and iron. This indicated that the pin and bushing was wearing about equally. We were surprised at finding considerable lead, and were puzzled until it was remembered that the pins had been protected by white lead when shipped. Evidently some had remained on the pin when it was put in service. While on this subject, it might be well to state that samples of oil were also taken from the center bearing, but analysis showed no trace of either zinc or iron. Evidently any wear debris was too heavy to be carried over the top of the chamber.

As designed, the centering latches were placed at each corner, but difficulty was found in properly adjusting them so that the bridge could be reversed, so two of the corner sockets and plugs were removed, leaving those on the diagonally opposite corners. This arrangement works perfectly. The Willamette bridge actually stands almost northeast and southwest when closed. A very decided side warp from sun heat develops, one direction in the morning and opposite in the afternoon. For a time at the Vancouver, when one track only was laid, excessive loads were put on the latches in locking up without reversing. This shows at once on the instrument in the operating house. All the bridges were made perfectly reversible, so that as soon as any latching difficulty is noticed, at the next operation the bridge is reversed and the sun soon corrects the difficulty. However, if the bridges had not been made reversible this side warp would have caused considerable trouble and it is doubtful whether the latches would have stood the service as they have. In any case undue strains would have been produced in the lower lateral bracing. It seems imperative that bridges of great length should be made reversible.

More actual droop at the ends was found than the calculations indicated, and as the ends had not been erected high enough the rails at the ends had to be readjusted, which was done by lowering those on the approach.

As stated, the Vancouver sets were put in service first and set for the calculated lift of 1½″ for normal conditions. During a period of high water in the Columbia River and also when the water was very cold, a morning opened bright and hot. Trouble soon developed in lifting the ends and at one operation the motors almost stalled. At that operation the instruments showed a current producing nearly 90 H. P. for each motor for an instant. Observation showed the droop was then nearly two inches.

It was decided to reduce the lift to 1¼″ for normal conditions, which was done at once, necessitating a readjustment of the tracks. Observations of chord temperatures were made that morning by

placing a thermometer bulb against the steel, held on by a ball of putty, on the inside of each top and bottom chord. There was found a difference of 20° F. of the exposed member between the top and bottom chords, and about 5° F. difference between the two bottom chords. This explained the cause of the trouble. The load for normal operations is a little high on the motors and seems to vary considerably. This, of course, takes place considerably before the locked position, due to the action of the toggles, which require the greatest operating force in this design at the time the ends are about half way up. It is practically impossible to get at the actual efficiency of an end lift of any form, and judgment as to efficiency can only be based upon the action of the principle used in situations where the efficiency can be measured. The examination of all parts of these lifts did not disclose any indication of excessive friction that would lower the well-known efficiency of the toggle and the gear train. Yet it is a fact that the lifts are rather under-powered. Observation of many forms of lift devices discloses the practically universal under-powering of all, and that in modern bridges with the usual speed of lifting, it requires fully as much power to lift the ends as it does to swing under over-normal but not maximum conditions.

Further, the abnormal or maximum conditions occur much more frequently in the end lift than in the swing.

The above would indicate a conclusion that a revision of the assumptions and calculations regarding end reactions, and the amount of actual load during various parts of the lift would be a good subject for investigation. The writer's assumption that the load varies directly as the lift does not seem to be correct, as there usually appears to be a peak in the load earlier than this assumption gives.

The rail locks and all machinery are alike on all the bridges. The rails at the bridge gaps are open 4″. At each side of the gap the head at the outside of rail is planed off near to the web and a shoulder ⅛″ deep is made under the head as shown in Plate VI.

Steel castings are fitted to the rail as shown in the enlarged section. One casting for each at the inside of the rail forms a support and also serves to hold down the rail. On the outside of the rail the casting holds the rail down and is also made to serve as a guide for the joint key to fit and slide in. The whole device at each rail end is bolted to a ¾″ cover plate, which in turn is bolted to the ties.

The bolts attaching the castings to the plate are all 1″ turned bolts in tight-fitting holes.

The cover plates rest on bent "U" plates ½″ thick, which are fitted over the ties.

The castings on the approach are shorter than those on the draw, and form sockets for the key when they are locked.

The connection of the rails is produced by sliding, across the gap. The keys are about 5 feet long and are made of forged, low

carbon tool steel slightly hardened on the top. They fit in the side and under the shoulder of the rail. The top is beveled to suit the bevel of the outside tread of the wheel, which rides on the key in crossing the gap. At the gap the key is 5/16″ higher than the rail and from there tapers down to below the top of the rail. It is thus seen that the wheels, in crossing the gap, ride up and then down a slight incline and thus cross without bump or jar. In fact, unless one knows that such gaps are to be crossed he does not notice it at all. There is a slight click to be heard and a lifting of the wheels noticeable only when crossing at a speed usual on draw bridges. The keys at each end are connected by links to levers mounted on one cross shaft, located just under the rails in bearings attached to the ties.

The drawing shows the relations of parts for the unlocked conditions. The keys have a travel of about 26″ and when properly adjusted the centers of the end of the levers go to a point below a line from the center of the shaft to the center of the pin in the key, thus locking the keys against any return action. I say properly adjusted for reasons that will be brought out later.

Each cross shaft is rotated by means of a pinion and segmental gear, the bearing of which is attached to one of the stringers. The segmental gear is operated by a link connecting to a crank on a gear which is rotated by a pinion mounted on the shaft of a worm gear. It is thus seen that no damage can be done by the continued action of the machine, as this would only cause the keys to move in and out continuously.

The worm gear and worm are inclosed in a case on which is the bearing for the crank gear, and the case is bolted to the stringer. The worm is driven by a high speed 3 H. P. motor without speed control. The motor is also bolted to the stinger. Your attention was called to the location of this machinery, and that it was in the same enclosed compartment as the end lift machinery. The examination made after actual service disclosed that of all the equipments this portion of the operating machinery had given the most trouble, although the condition at the time was good, except the keys. They were quite worn and required replacing. About all the trouble was traceable to the guides and sockets of the rail. Several breakages had taken place and the curious thing is that, though the breakages had all been at the gear case and associated parts, no two had been of the same part. The rail lock sets, six in all, are exact duplicates on the three draws, but most of the breakages were of the Vancouver and Oregon Slough sets.

The rail joints of later bridges have been improved, largely from experience gained in installing and from the examination of these devices. It is possible that these improvements may be shown at a later date in relation to a later design of bridge operating machinery.

In installing the rail locks, especially on the Vancouver draw, it was found impossible to align the bridge with sufficient accuracy

that the keys might enter their sockets freely. Some side play had to be allowed in the latching sockets, and even a spring or giving of the latches when locking up under a large side warp would leave the sockets out of line with the keys. Under this condition, in attempting to lock the rails, the key would jam and two breakages, one of the worm gear case and one of the crank boss in the gear, were caused by this trouble. It was found that the 3 H. P. motors had fuses capable of supplying 12 H. P., and as the motors were running full speed at the time the jam occurred, the full 12 H. P. would be available, or at least enough to break something.

The fuses were changed to 4 H. P. as soon as they could be procured, and breakages from the above cause were stopped. To correct the trouble the sockets had to be made movable side-ways about ¼″. This was done by lowering the cover plate ½″ and bolting the two castings to a ½″ plate under the rail, the two outer bolts tight with counter-sunk heads and the others loose in slotted holes. The rail was not spiked tight for the first 10 feet. The four back bolts held the rail from tipping or lifting and the key produced the proper gauging of the track. This works well. In replacing the broken parts, in some way the adjustment of the levers spoken of as the proper one, was not produced, and the levers were left with their centers above the line, between the shaft and key pin centers.

For a time, in switching around the Vancouver yards, a heavy locomotive frequently came onto the bridge. In starting a heavy train the traction of the drive wheels acted to throw back the key. As the levers were not fully down and locked the continued action on keys gradually worked them back until some part of the locomotive caught on a lever, with the result of several breakages. The worm and gear work very freely and though theoretically locked, a continued jar on the connections ran the worm back.

Switching on the bridge was stopped and breakages have stopped. But the breakages call attention to the importance of well underlocking the levers. The small shoulder under the rail to keep the key down is far too small.

At the time of the sleet storm spoken of earlier, in relation to the trouble at the Willamette bridge, and after the bridge had been gotten open the ice collected on the top of the end lift rollers about ¼″ thick. In locking up again the ice did not crush and the rails on the draw were ¼″ too high. This the operator could not see and he attempted to lock the rails. There being insufficient shoulder, the key jammed side-ways in the sockets and the fuses to the motors blew out. The keys were so jammed that the motors could not pull them out, and, of course, the draw could not be swung to get at the ice. Considerable train delays were caused until the keys could be disconnected and driven out, the ice cleared off, and the keys gotten in place again. Had there been sufficient shoulder on the key, they would have been stopped by the socket without jamming.

Further, this shoulder seems to hold the rails together and prevent derailment should there be any tendency of uplift at one end due to a very heavy live load on the draw.

ELECTRICAL AND MAIN POWER EQUIPMENTS.

The demand of the conditions at the two main bridges, Vancouver and Willamette, were so severe, especially regarding reliability of service, that the most careful considerations were given the question of power supply.

Storage batteries and one main generating plant owned and operated by the railroad company; and connecting to the service of the Portland Railway, Light and Power, were the chief methods considered. It was finally decided that the most reliable and economical plan was to connect to the power company, who had a substation near the top of the cut near the bridge approach on the St. Johns side.

The current there is three phase, thirty-three cycle alternating current at about 30,000 volts, and is transformed down to 9,000 volts. At this potential it is connected to the railroad's line about three miles long and to transformers in houses on the approach to the Willamette and Oregon Slough bridges. The step down here is to 440 volts. The connection at Oregon Slough operates both the Oregon Slough and Vancouver draws.

The charge for the service as finally contracted for is with a low minimum, it is stated, rather below what has proved to be the actual requirements, and a power charge cheaper than the railroad company could generate.

The power to all the bridges mentioned is connected through submarine cables. At the Vancouver and Oregon Slough draws the center pins are hollow and the wires are brought through to electric turntables attached to the pins.

At the Willamette no such connection is possible. The cable is brought in under the turntable pedestal to the center casting. The wires are then taken through the grooves at the joint, mentioned earlier, of the retaining ring, part one side and part the other as shown in Plate VII.

Attached to the ribs of the retaining ring are contact brush holders with slate insulation. Above, attached to the ribs of the top castings, are copper rings on slate insulation. The lowest ring is above the top of the retaining ring. This electrical turntable has a capacity for the current on three lines, capable of producing 500 horse-power at the motors. There are also wires for the pier navigation lights and telephone wires. The whole device is roofed over to keep off rain and drip.

Though the room was rather small, the device has proved perfectly reliable.

On the two main draws, for use during construction and also in case of any derangement to the electric service, are complete generating plants, consisting of a gasoline engine and generator and all

wiring connections, switches, current control, etc., so that the service may be changed through one main switch from the power service to the independent service. The outfits are practically duplicates, except as to amount of power and the manufacture of the material. They are located in houses mounted on framing attached to the main tower posts, just above the car clearance.

These houses are of wood, sheeted with metal outside, about 20 ft. square, with bay windows on the sides of the longitudinal center of the bridges, and also with ample windows on the other sides. They are very light and comfortable. The houses also contain all the operating and controlling machinery.

The different contractors furnished the outfits. The engine at Vancouver is three cylinder, rated at 125 H. P. and has a spur gear drive to the generator. This had the longest service during the construction work and has proved very reliable. There is some vibration, as is to be expected from a heavy slow-speed engine mounted on an elastic floor

The engine at Willamette as shown in Fig. 4, is of a different manufacture, four cylinder, and rated at 165 H. P. It is direct connected to a generator. This engine is far from satisfactory. Though theoretically a 4-cylinder engine is more easily balanced than a 3 cylinder, this engine is badly balanced. The vibration is very excessive and though many attempts were made to correct or reduce this, short of removing the shafts and pistons and properly balancing these, the vibration is still bad and causes considerable trouble. It would have been rejected but for the serious delay caused to the opening of the bridge while a new engine was installed or that one was rebalanced.

As first installed the exhaust pipes were standard gas piping, connected to one large pipe through the house to an exhaust muffler attached to the lower bracing outside the house. Bends were made in the branches to allow for flexibility. But the vibration made it impossible to maintain the packing between the cylinders and the heads. This resulted in leakages of water and short-circuiting the firing apparatus of one or more cylinders, usually at the most inconvenient times. In a 4-cyl. engine, if one cylinder is inoperative the power is reduced apparently about one-half. So much trouble was caused by the leakage that the exhaust connections were made of flexible pipe. This helped, but did not cure the trouble, and is expensive because the first cost is high and the flexible pipe burns out rapidly. No packing has been found that will hold. At the time of the sleet storm the engine went out of efficient service from firing trouble. The generator has given very good service.

The switchboards, as shown in Fig. 5, are of black slate and contain all the switches, circuit-breakers, recording instruments, current control, indicators, etc., and are quite large. The instruments and devices are all of the highest grade and all metal, bright copper finish.

The purpose of each switch is indicated by a label so that the operation of the board is easily learned. In addition to the board

measuring instruments, there is a recording watt meter mounted in front of the operating stand which gives a daily record of the bridge operations, including the amount of maximum power used at each, and which also is used by the operator as the indicator for the application of power, step by step, when swinging.

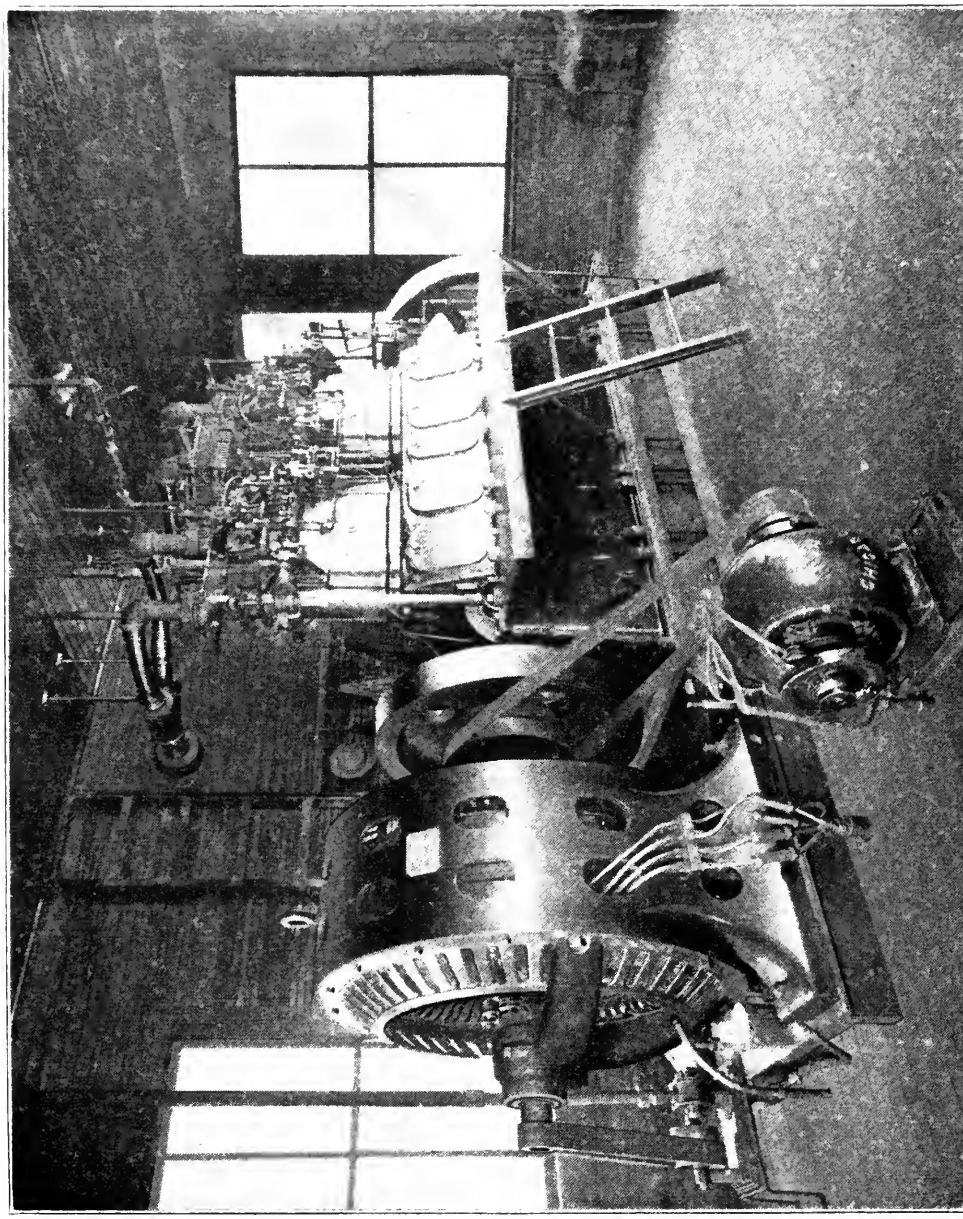


Fig. 4

On account of the vibration from the engine, it was required to mount this instrument on springs.

The control of all the motors is arranged in one operating stand located in one of the bay windows. Each motor has a separate controller of the reversing drum type. Those for the rail locks have a handle for each. Both controllers for the end lift motors are

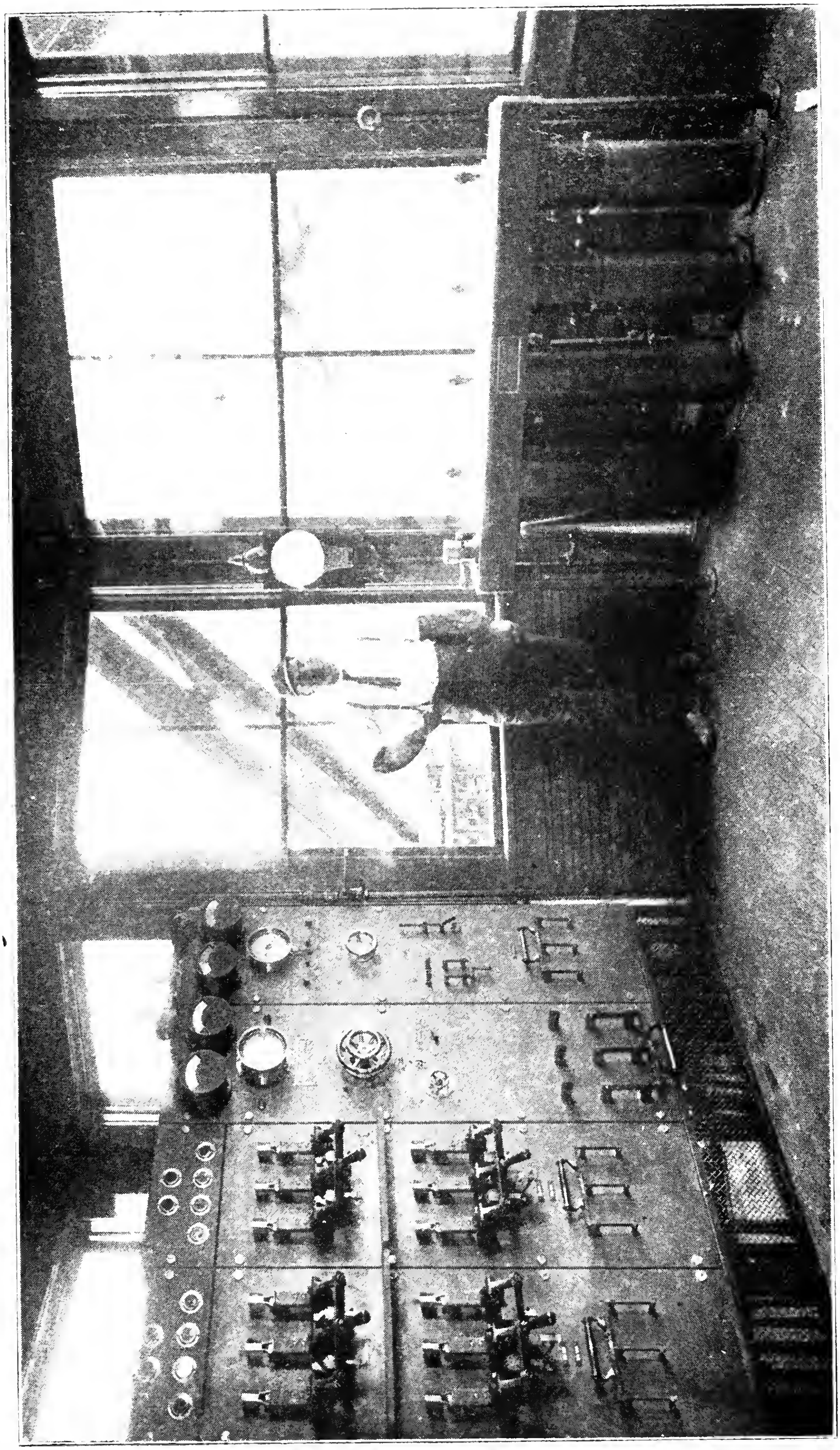


Fig. 5

gear connected to one handle, and also the two controllers for the swing motors are gear connected to one handle. See Plate VIII.

The valve controlling the brakes on the swing trains is also located in the operating stand. The operating handles of all the devices are mechanically interlocked by a system of cams and tumblers, very similar to a combination safe lock, so that the operation must proceed in a fixed relation and direction. For instance: when the bridge is locked safe for train use, the only unlocked levers are the two rail lock handles and the brake valve lever.

To swing: both rail lock levers must be moved in the direction to unlock the rails and then returned to the neutral or center position before the end lift lever is unlocked. The end lift lever must be operated to unlock the lift and then be centered, to unlock the swing lever, and, of course, locking the rail lock lever.

The swing lever may be moved in either direction, but in so doing everything else is locked, including the brake valve handle. Moving the brake handle can only be done when the swing lever is central and also locks it in this position.

In locking up, the routine must be exactly reversed. If in doing any operation any lever is moved in the wrong direction the lever for the next operation remains locked.

The completion of the operation of each device at each end of the movement is indicated by lights behind colored lenses in an indicator box. Three lights for each, showing the locked, intermediate and unlocked positions.

The rail locks are stopped at the locked or unlocked positions by the operator centering the controllers as indicated by the signals.

The end lifts are stopped automatically, as stated earlier, but the operator has the indication from the signals and also sees the circuit breakers open for each.

A contact is made at the end of the bridge, lighting a white light when the bridge is within the allowance for centering by the latch plugs. There is also a similar signal for the full open position of the bridge.

There are no arrangements for locking or unlocking the operation of one device by the movement of another.

Although the operators who have been employed are not above the average intelligence of men usually employed in such a capacity, the experience on these bridges indicates that they can be absolutely depended upon not to operate one device before another had completed its motion. No accident or delay has ever been caused by such a wrong application. On the other hand, the mechanical interlock, insuring the correct routine, prevented several mix-ups, especially at first.

An automatic back-locking would have been very complicated on these bridges and, as shown by experience, an unnecessary expense.

The swing motors are controlled by resistance in the secondaries. These sets of resistances were located first behind the switch-

board in the house. But they got very hot, so were located in a nest outside the house in a metal rainproof covering. It soon developed that the electrical manufacturers had conceived these as only a motor starting set for little or no load.

Trouble began when frequent operations were made until the grids burned off, sometimes red-hot pieces dropping to the deck below.

A temporary set of water resistances had to be used until a new and larger sets of grids could be procured. At the time of the sleet storm this latter set broke down and another set was secured. This last set has about three times the current carrying capacity of the first. This and other experiences leads to a belief that manufacturers of motors do not understand the requirements of bridge operations, and cannot be depended upon to establish the control of motors especially for the very heavy demands not only liable to occur, but that do occur frequently.

There is an automatically controlled, electric driven air compressor for supplying air for the brakes and for the river signal whistle. The whistle is controlled by a cord with a handle located just above the operating stand.

In the attic of the house, on supports attached to the tower bracing, are two air storage tanks of 25 cu. ft. each and an open water tank 8 ft. diam. by about 5 ft. high for cooling water for the engine. Above this tank is a ventilator for the escape of heat and steam. This tank of water was raised to boiling several times during the period before the electric power lines were connected. Provisions were made to fill the water tank by means of an air lift.

A tank of about one barrel capacity having a foot valve and strainer at the lower end is sunk in the river, under the protection pier, below the low water lever. A pipe leading from near the bottom of the tank, air-tight through the top to the top of the protection pier, is fitted at the upper end with a car air brake connection and hose, and serves as the water supply pipe. Another pipe threaded into the top of the tank is also fitted with a hose connection. On the bridge and so located as to come over these pipes when the bridge is closed a certain way, are two connecting pipes, one having a check valve in the bottom and goose-necked over the top of the tank is the water pipe. The other, fitted with a three-way cock at the bottom and connected into the air system, gives the power. When the pipes are connected, turning air pressure into the submerged tank forces about a barrelful into the upper tank. Then, letting the air out of the lower tank, the check holding what water is in the riser, the lower tank fills and the operation can be repeated as often as necessary.

Gasoline is raised from a large main storage tank below the railroad deck to a small service tank at the house floor level by a similar means.

There is a complete lighting system for the bridge house and

also convenient outlets for a portable connection at each machinery set.

Also all the navigation lights for the bridge and piers are fitted with three low power globes connected in parallel, yet so arranged that the change to kerosene can be made at each light in about one minute. The navigation lights are controlled by switches on the board. The above systems are connected only to the power lines, through a transformer reducing the voltage to 110 volts and so connected as to switch the circuit between any two of the three phases.

The lights for the operation signals can be connected to the exciter of the generator or into the main lighting circuits. In case of failure of all the power lines, the signals, which are only necessary when operating, are operated by the exciter.

The main power transformers are located in fireproof houses located on the ground close to the approach steel of the bridge.

At the Oregon Slough and Vancouver bridges the connection is direct by submarine to the Oregon Slough, and by a long submarine and long low-tension lines laid on the bridge and viaduct deck to the submarine cable of the Vancouver bridge. At these bridges this arrangement has proved very satisfactory and has caused no trouble.

At the Willamette bridge the connection is by a short low-tension connection over the two fixed spans to the submarine connection.

The sleet storm developed that the transformers were too low in capacity and larger ones had to be installed.

All the wiring on the drawbridge, piers, etc., is laid throughout in water-tight conduits and special care was taken to combat the damp climate of the region.

The three-phase operation, especially of the automatic control, signals, etc., is very complicated and the wiring diagram of the bridge is somewhat of a puzzle. Yet as finally worked out the arrangements are very practical and effective. No serious trouble or delays have been caused by any failure of the wiring or contactors. During the testing and adjusting there was considerable fireworks, but no particular damage was done.

After the bridges were turned over to the railroad company a complete system of track interlocking and signaling has been installed. The writer does not know the details of the system, except that he observed a distant and home signal for each track and believes there are also derails for each. He also observed and was told some peculiarities of the outfit.

The bridge itself is not interlocked with the track, but can be swung at any time, and is also completely reversible. The first operation to swing automatically throws every track device to the danger position. This he believes is the proper consideration of the signal position of a drawbridge, for the principal reason that the laws do not consider that navigation is in any manner the same as a tenant or secondary crossing and must always be given right of

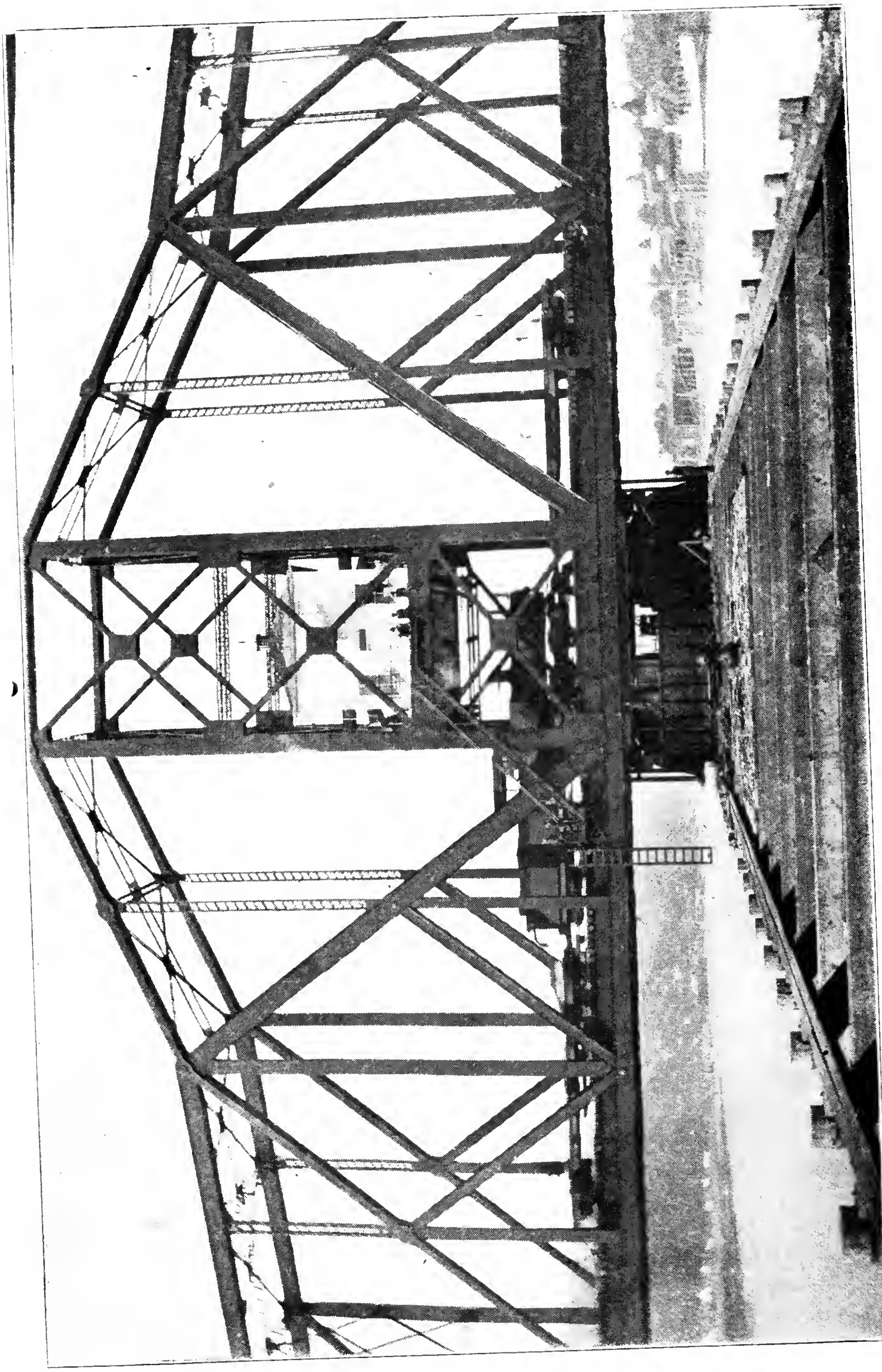


Fig. 6

way, and also there is no device to derail or stop a boat, especially if it is out of control by current or otherwise.

The signal connections are made through a peculiar series of contactors arranged one above the other vertically but operating horizontally on two diagonally opposite corners of the bridge with contacts correspondingly mounted on the approach.

The contacts are controlled by a connection to the rail-lock shafts so that when the keys are withdrawn the contacts are broken and opened clear for the swing. No matter what position the levers in the machine then stand, at the breaking of the contacts all devices go to danger. Nothing can be cleared until the rail keys have returned to the full locked position.

The wiring is so arranged that no matter which way the bridge stands when locked, the lever and return signals, as well as the train approach signals, are the same, the routine of the operation is the same and each lever has the same function. It is stated that it works perfectly, though having been put under some severe tests by train and navigation conflicts.

At the time the bridges were planned the demand was made that the Willamette bridge should be made capable of being opened, at least, in case of the failure of the entire machinery outfit. The hand device for the end lift has been mentioned, and in case of a breakage of that gear train the segmental gear can be worked back by crow bars. The rail locks can be disconnected at the keys and the keys pried back. To fulfill the requirements, the swing had to be independent of even the main rack.

This was done in the following manner:

On the lower flange of the drum heavy connections for hooks are fastened at two places and between these are guides for a heavy wire rope. A wire rope about 80 ft. long with hooks is provided and also steel twin pulley blocks with a coil of rope. On one end of the protection pier is fastened a heavy anchorage for one end of the pulley outfit and back of this a geared ship's capstan is fastened to the pier. The capstan, shown in Fig. 6, has eight bars for two men each. The plan is that in case of necessity one end of the cable is carried about ¾ of the distance around the drum and hooked to the fastening. The other end hooked to the pulleys, one set of which has been attached to the pier. Then 16 men at the capstan winding in on the pulley rope will swing the draw. Of course, it would be slow—figures to take about 40 minutes, but it would open the draw. It has never been used, and probably never will be. It was not even tested, but it was provided complete.

In conclusion, it may be well to state that such adverse criticisms as have been given herein have been with the idea of leading to the improvement of similar outfits in the future. Although the machinery and electrical outfits of all the bridges are not perfect and are capable of being improved, they are very practical, have stood up well under the demands of service and even of some very severe requirements. The cost of maintenance and repairs has been surprisingly low.

September, 1916

DISCUSSION.

C. H. Norwood, M. W. S. E.: In the vertical shafts of the turning machinery, Mr. Carter, did you observe any perceptible wearing in the collars—the washers that carry the thrust?

Mr. Carter: On the main shaft?

Mr. Norwood: Yes, on the main turning machinery.

Mr. Carter: Very little.

Mr. Norwood: Was it scarred in any way?

Mr. Carter: I scratched off the grease and could not see that there was any appreciable wear. Of course, the inside of the thrust collar on the shaft and the outside of the bronze washer are about the same, so that there would not be much of the collar worn; but apparently there was no wear.

Mr. Norwood: Are all these bearings carried on the bottom?

Mr. Carter: Everything is carried on the bottom.

Mr. Norwood: Is the lens construction of the center bearing absolutely necessary if you key the upper and lower bearings?

Mr. Carter: You mean in the center?

Mr. Norwood: The main center bearing of the bridge. You said that you did not think the lens construction had a perfect bearing. That is a very hard thing to accomplish mechanically, whereas, if you put a flat lens in there, you can get an absolute bearing and then key the upper and lower wearing surface. There is very little side motion or end motion, so a flat lens could have been used there, it seems to me, with very good results.

Mr. Carter: I think I will never put in another spherical lens. They are expensive, and, as Mr. Norwood says, it is a very difficult thing to get a fit unless they are scraped together, and in scraping them together you have to depend upon getting a spherical surface originally and you have to depend upon a template for that. Unless you go about it in the scientific way opticians do, it is almost impossible to get that curve, and unless you scrape those two together you are not going to get a good fit; whereas, with a flat body, you can get a plane surface. The amount of teeter is not so much but that the elasticity of the connections there would make a flat bearing perfectly practicable. There is absolutely no necessity for a spherical bearing in this case.

Chairman Lacher: That is, the situation is different from that in which you have a center bearing, as in a turntable?

Mr. Carter: In a turntable you have teeter and must take care of your angularity of action. But in a bridge 500 feet long you have a very small amount to take care of. The elasticity of the steel itself will take care of all that without any trouble, and with a well fitted drum and roller ring there is practically no teeter at the center.

Andrews Allen, M. W. S. E.: If the bearing should have a decided tendency to teeter, would it not be better to have the flat disc

anyway and provide for the teeter with a rocker bearing above the disc?

Mr. Carter: Yes. The only trouble with that is to get it in both directions.

Mr. Allen: I had that same trouble in a disc on a turntable where there was a considerable teeter. I attempted to carry it on spherical discs and it did not work.

Mr. Carter: Of course, if you attempted to take care of both directions you would have to have double joints at right angles. If you have a rim bearing and it is carrying five-sixths of the load and the rim is square, or nearly so, I do not see how you are going to get any teeter. You will hardly get a thousandth of an inch in a radius of about 27 inches.

The worst thing about the whole matter was those two different radii. They followed precedent on that. We apparently have a tremendous bearing on the inside of the center where the area is smallest, and nothing on the outside at all. Oil easily flows through.

Mr. Norwood: I had some experience with a drawbridge at Clinton, which, I think, will demonstrate the point we have in mind. That is a case where the lenses did not set perfectly. Immediately when the bridge was swung they tilted and they stayed in that position, the greater part of the load being carried on the outer rim of rollers. It never gave any trouble and was never changed.

Mr. Carter: They did get it back, at the Clinton bridge, but they had a very difficult job. They had to jack up the bridge to get it back. One of the bearings had got about 3/16-inch out of center. Unfortunately, there was an allowance made on the inside of the retaining ring of ¼-inch on each side, which permitted the center bearing to be erected out of center.

Another thing I did not bring out on this center question—you have two bearings—two surfaces. Somebody, apparently, had a theory that each one of those surfaces was going to turn half the time. They do not. It turns on one or the other always. If there is one-thousandth of one per cent difference of coefficient of friction between those surfaces, which may be due to a difference in lubrication or the collection of debris, they are always going to turn on the one that has the lowest coefficient of friction. You might just as well eliminate one of the two surfaces.

Years ago I had the experience of putting up two beautifully made ground roller bearings, one above the other. The intention was that they would each turn half the time and the consequence would be the speeds of the rollers would be half what they would otherwise. There was no way that we could get both of them to turn at the same time. They would turn first on one and then on the other. One would turn until the oil wore off it and then the other would start.

Mr. Norwood: There are one or two things I think worth speaking of, not with reference to this particular piece of work, but other work that I have had experience with. The main bearing of

the main pinion, I think, is one spot on a bridge that is liable to give as much trouble as any other, and I have noticed that the bolts sometimes shear off, with a sudden application of brakes. As Mr. Carter says, in the Willamette bridge they were specially reinforced. I think that was a good point in the design. If it needs reinforcing it certainly needs reinforcing at that point—that is, the bearing point of the lower part of the drum. Frequently, in work of this character they do not seem to use strong enough construction and the least wearing in the rack will cause side strains which are liable to throw extra strain on the bolts.

Mr. Carter: There was an experience on the Vancouver bridge in regard to the main bearing connection that will give some indication of what the strength was. I was trying to make a series of tests to determine what the power requirements of acceleration were in a large bridge. We got along very well with the tests, but the instruments were out of order and we were not able to get the proper records. I put up a little platform to work on, consisting of two by eight Oregon fir planks. I tried to get the coefficient of friction by measuring a certain speed and the length of time required to stop. In so doing we overran on to the platform and ran a two by eight fir plank between the teeth and crushed it completely. It was packed solidly in the teeth and had to be chipped out as if it were metal. That did not overstrain those connections at all. I examined them very carefully. They were broken later by vibration, but at Willamette you cannot even feel a vibration when they are putting on the load and starting the enormous mass.

I tried to bring out in the paper that part of the connection under the drum which is so often not properly considered. Designers seem to think that anything will do there, and they seem to have no idea of the loads caused by unbalanced wind load or such a condition as we got when we had ice on the track. We applied 160 horsepower, all we could get, until the engine got out of condition. In electric power between 200 and 300 horsepower went into it. Then the transformers got hot and we had to cut them off and use the tugs. The load is enormous. It figures on ordinary application 150,000 pounds. The Willamette bracket is a good one. It is capable of few improvements.

H. J. Hansen, M. W. S. E.: The paper states that the end deflection is 1½ inches. I should like to ask what percentage that was.

E. B. Bergendahl: The total deflection from the false work support was four inches, to which must be added that for temperature. What we lifted was the negative end reaction plus 20 per cent for temperature droop, which made it an inch and a half.

Mr. Norwood: This controller, set from a mechanical standpoint, worked very well, but the mechanical control gives you no indication at all as to the completion of the operation. In other words, after an operator has closed his swinging controller, that is, brought the lever to the "off position," he completes the operation and it releases the next. The bridge may be swinging, for instance.

There is nothing with this mechanical type of interlock to prevent him from throwing on his end lift controller. If the bridge is swinging there should be a device to prevent the release of the next operation (lowering end lifts), until the bridge is closed and only then can he release his lever for lowering the ends; but with this type of control we do not get that feature.

I will say that I was at Portland last summer and saw the rail locks from a slowly moving train and I think that that drawing is a little exaggerated as to their present condition. The tongues have worn down so that the motion of the wheels across the rail is not noticeable at all. I would not say it was by any means dangerous. It rattles slightly as the wheel goes across, but, so far, I should say, the sliding rail is still working very satisfactorily.

Mr. Carter: They run over that only at about eight miles an hour, but the road has one elsewhere, somewhat similar, over which they run at thirty miles an hour.

Mr. Norwood: In the diagram of the switchboard you will notice that the operations are all made by circuit breakers. It is very rare now that we use the circuit breaker for breaking a circuit. It is done by an auxiliary trip and a contactor. As is shown here, when the end lifts have completed their operation, either of raising or lowering, the circuit breaker trips and the operator moves from the position where he is standing at the controller stand and has to close the circuit breaker. With the present state of the art contactors are used instead of circuit breakers. If his contactor goes out for an overload or the completion of the travel, the operator merely centers the controller lever, and he can go on with the next operation. He does not have to leave the stand.

Another very bad feature on that switchboard was the placing of the signal lights on top of the board. That was very bad, as we have since learned. Now, all those signal lights are placed down in front of the operator. In fact, they are mounted on the controller stand so that the operator can watch the lights as he looks out over the bridge at the operation.

Mr. Carter: There is quite a controversy over this question of a back signal for the completion of an operation. There is nothing, as Mr. Norwood says, to prevent the operator from starting one device before another has completed its motion, but he has not done it. There has never been a single operation where they have had any trouble from operating one appliance before the other had completed its operation. I consider this back action an unnecessary complication which simply adds to the cost, especially of a big bridge of this kind.

Mr. Norwood: The operator did it at Clinton. He shut his centering devices while the bridge was open, and as he swung closed, the centering lock, which in that case happened to be an air lock, cut through the gusset plates as if they were cheese.

Mr. Carter: That was not the fault of the operator, but of the device.

Mr. Norwood: The operator became excited and lost control of himself.

Mr. Carter: That was caused by a leaking air valve, and was not the fault of the operator. I never have seen a case in which there was any trouble from the operator. These men, as I say, are men of not more than average intelligence; in fact, they are not of average intelligence, but they can be depended on to wait until that thing has completed its motion.

Mr. Allen: It may be interesting to know that I have had the same experience with a shaft turning in the wrong bearing. The only way to be sure that a shaft will turn where it is meant to turn is to key it where it ought to fit and then you are sure. I do not know where the first design for a stiff live ring came from, but I used it in 1901. It was on a bridge over the Illinois river, where it worked very satisfactorily, and afterwards on two drawbridges on the Chicago Junction Railway over the Chicago river. The bridges were not as large or as heavy as the ones described by the author, although the first one, if I remember correctly, was 350 feet long. I do not think I had a double channel inside the ring on the Illinois river bridge, but believe I did on the Chicago Junction bridges. Both had the same arrangement of adjustable short axles.

Mr. Carter: Did you have the washer go through the outside channel?

Mr. Allen: I do not think so. I think it was inside.

Mr. Carter: In this case the outside washer is keyed through the outside channel in a hole so the washer can play back and forth through the outside channel. I think this is the first occasion in which that method was employed. I know the precedent we had at the time was filling up the space between the outside channel and the end of the wheel with washers.

Mr. Allen: I do not remember just how we worked it out, but there was some scheme by which the rollers could be adjusted individually by nuts on the inside or outside.

Mr. Carter: It is a later design I have been connected with, of this same device, in which I have done what I outlined tonight. The live ring is made pretty stiff, but it does not have that circular cut diaphragm. It is an expensive undertaking to get that diaphragm in a circle. There is enough stiffness in a laced box girder of that form without that circular diaphragm. I put in small channels across where the bolts came, to take the thrust of the bolts from one channel ring to the other. The outer ring is very much lighter than shown on the drawing. It is a very small channel, and it is not held in any way. That was at what is called the Minnesota channel at Duluth, on the Northern Pacific, where they cross St. Louis Bay. It was constructed along practically the same lines as in this bridge, but not so well built; and when they riveted up the outer channel to the plates connected to the stiff ring, they forced the rollers out of radical position and in operating this ring they pulled the bridge about 7/16 of an inch out of center. The whole bridge had to be

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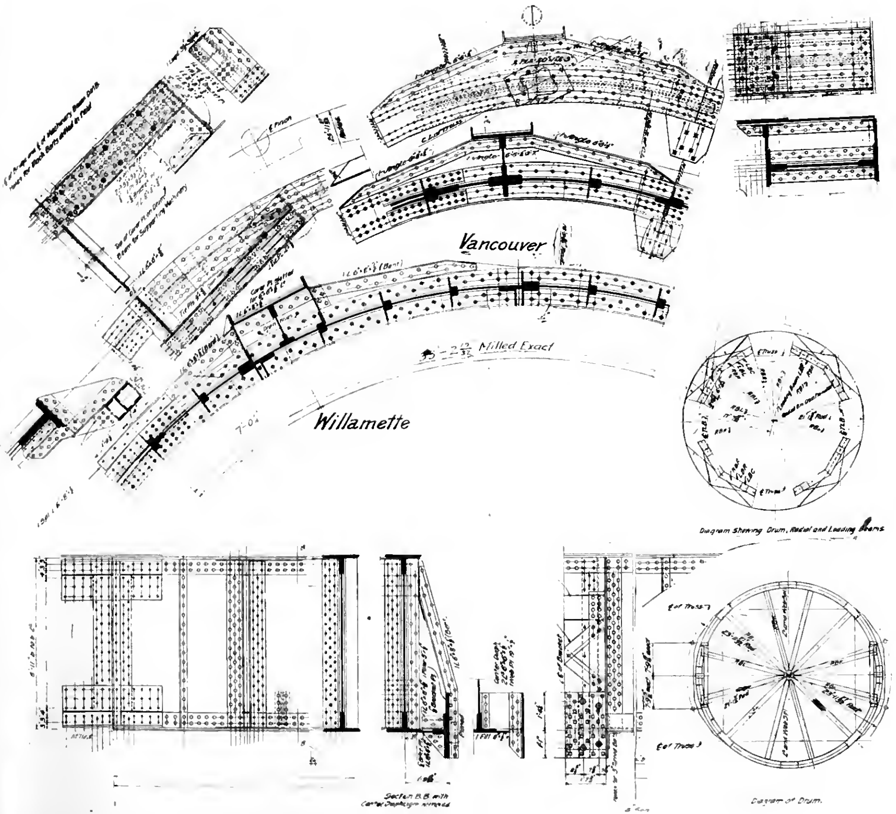


Plate II

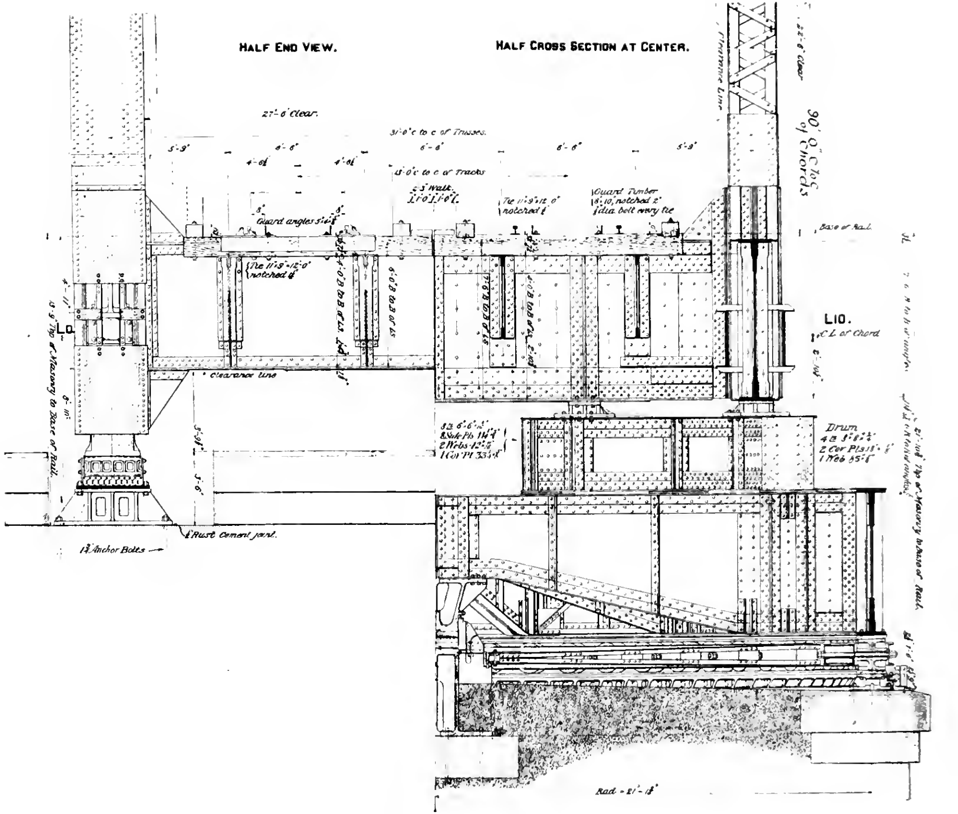
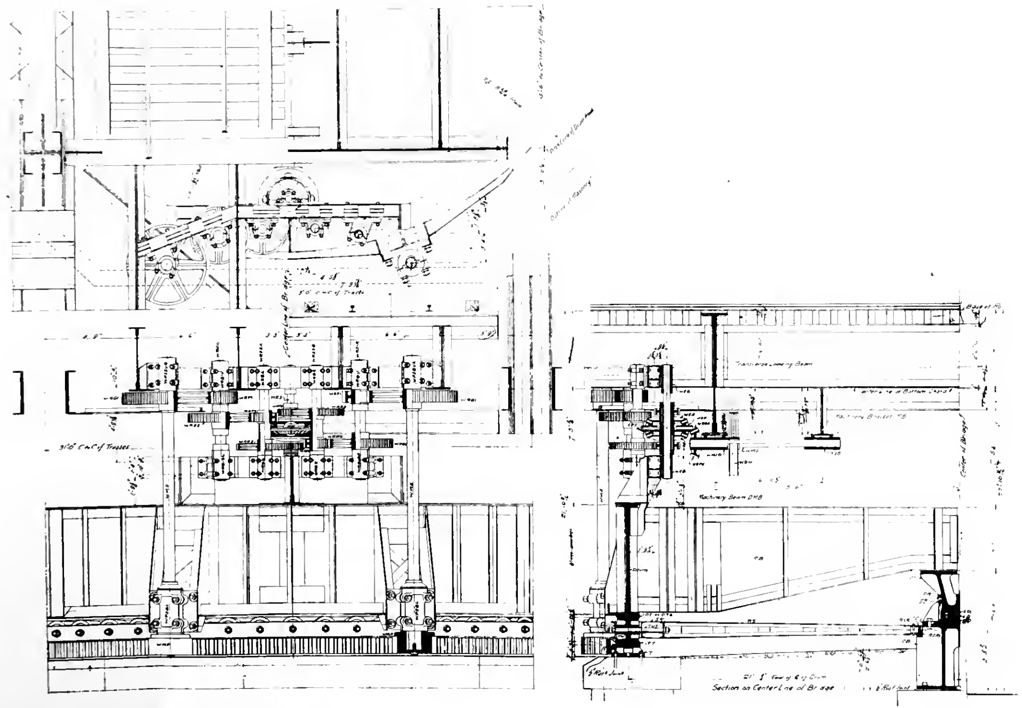


Plate I



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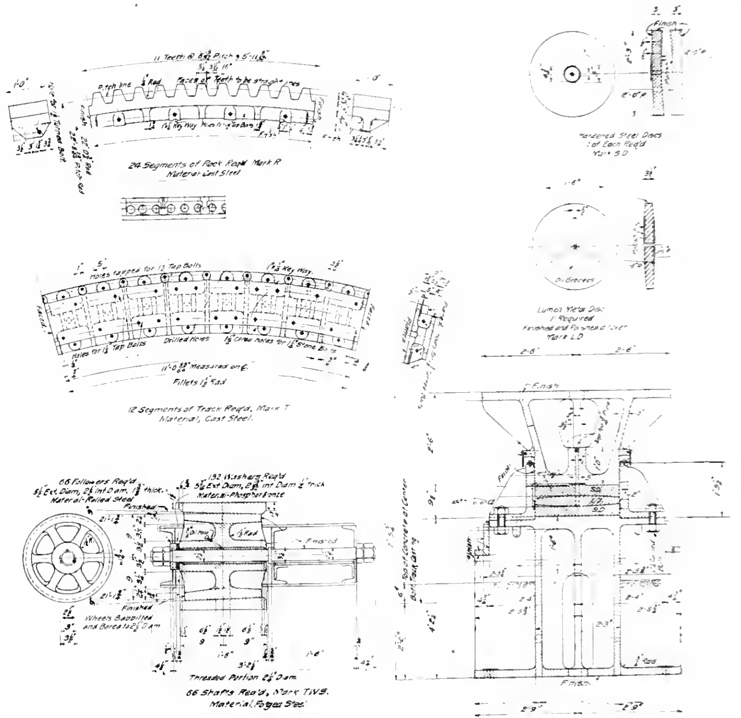

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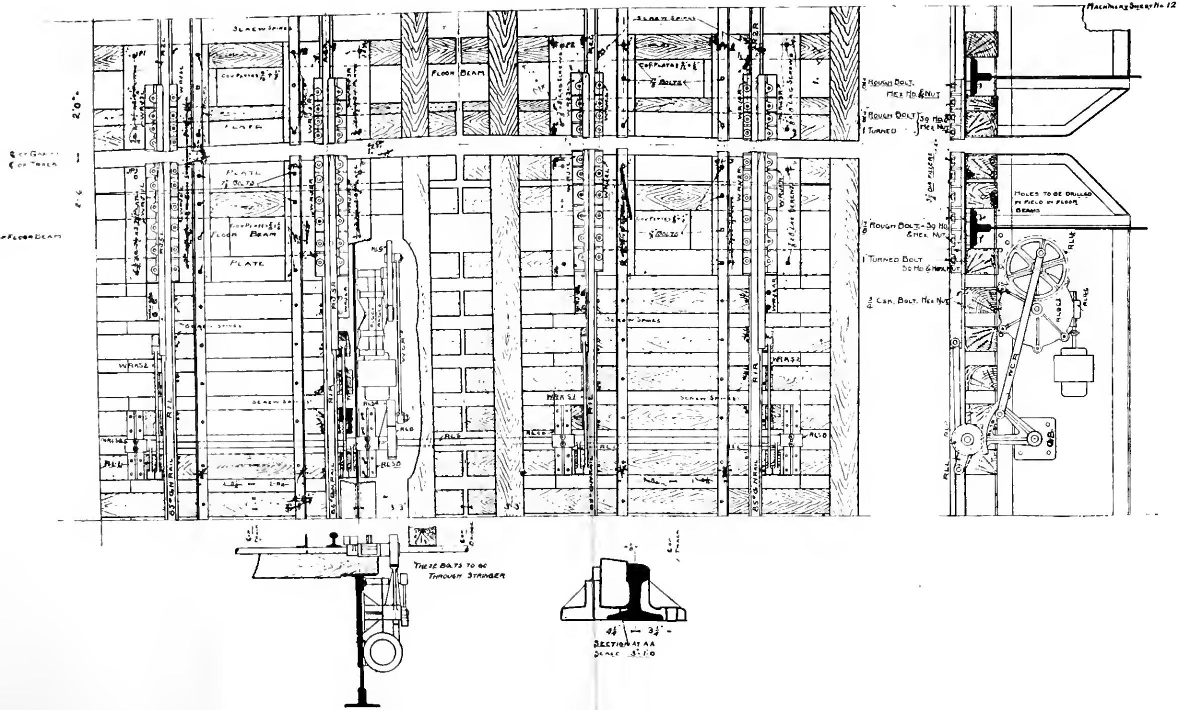

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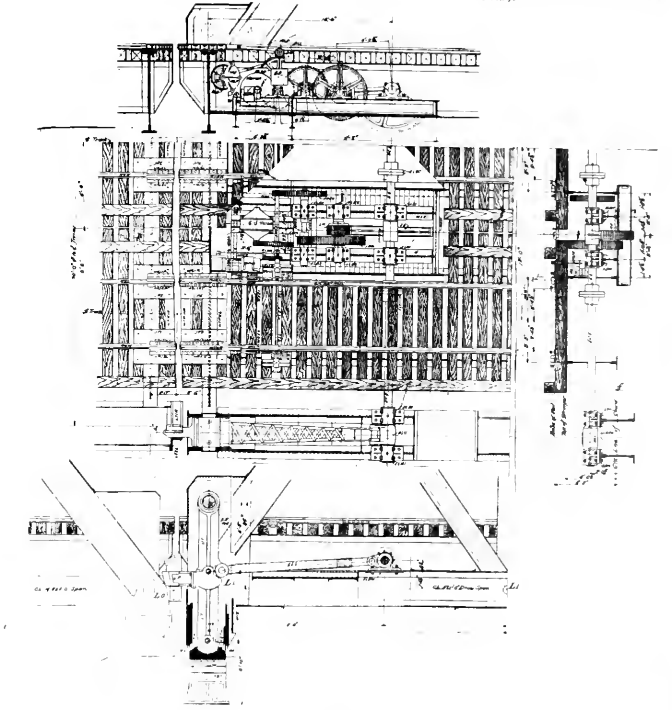

Plate V

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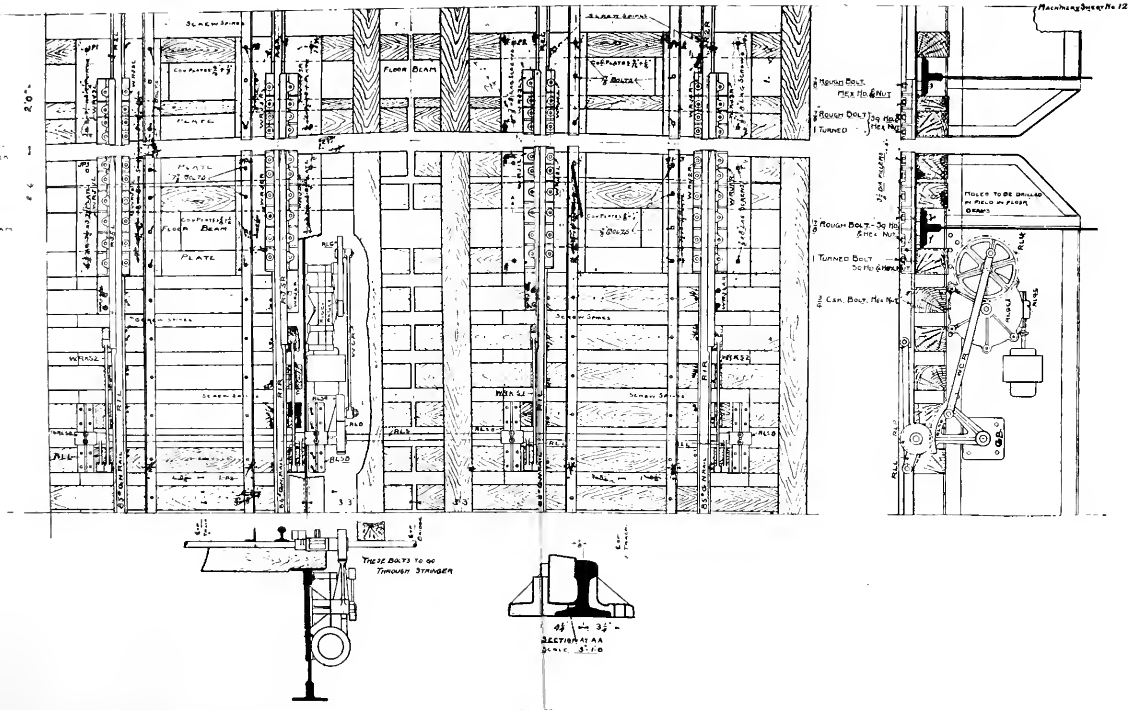

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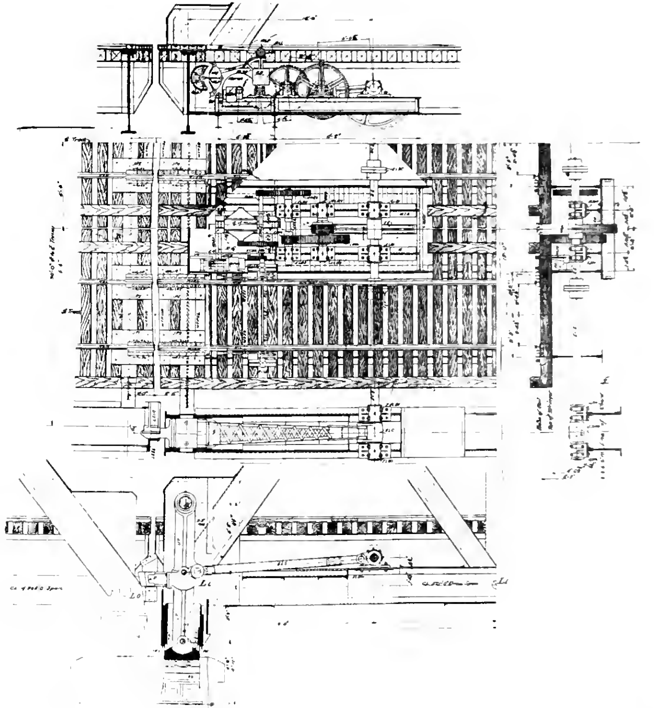

Plate V

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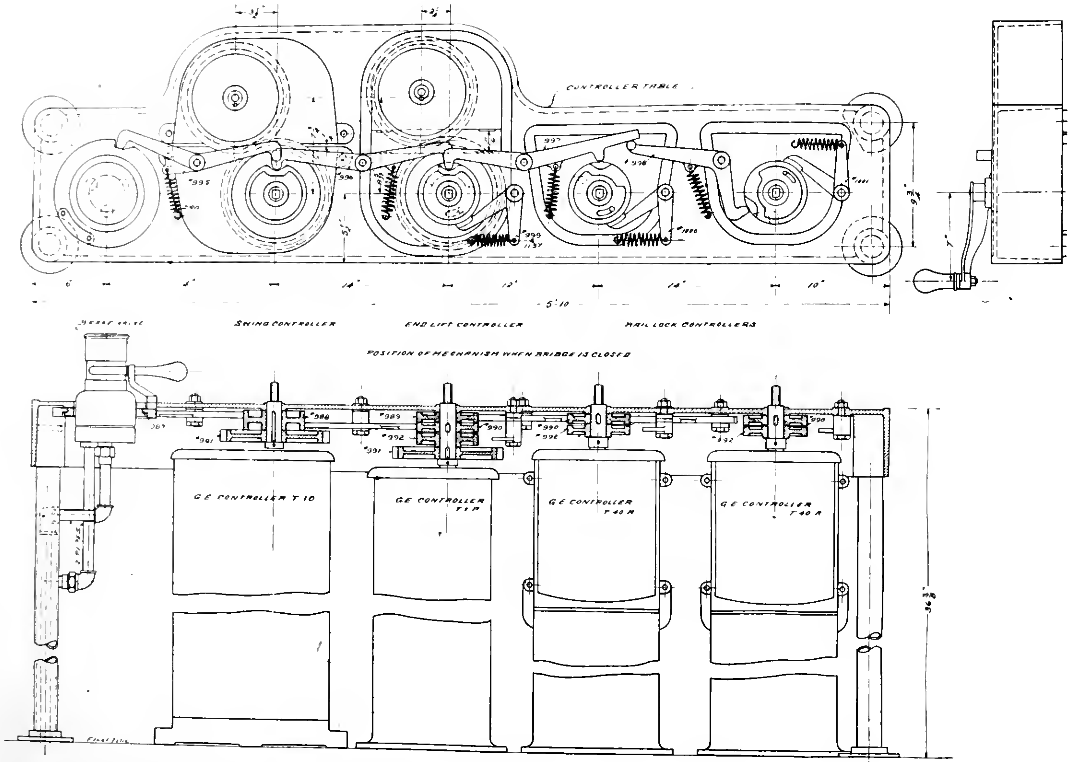

Plate VII

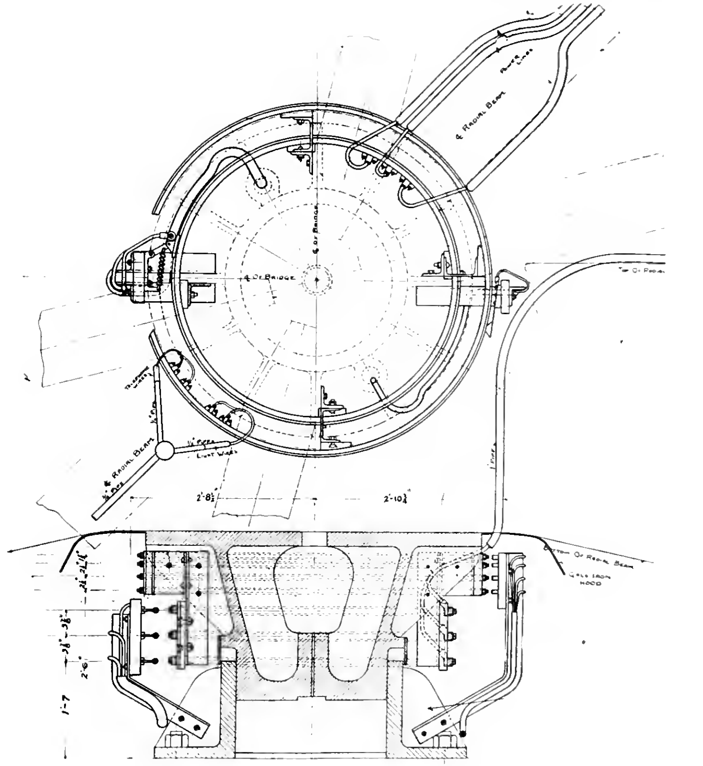

Plate VIII

jacked up and the bolts connecting the radials to the center ring had been partially sheared. That was due simply to poor field work. You cannot depend upon a bridge erecting crew erecting those parts in line. At the Oregon Slough, by putting an instrument over the center before the drum was put on, we found a variation out of the true radial position of those radial rods, of from 3/32 to 3/16 of an inch. This was corrected by using eccentric washers in the outer ring, of the proper eccentricity to get all the bolts radial. In the new design the outer ring is not riveted in any place. Some very light angles are bent down simply hold it parallel with the live ring—not radial, but parallel. The rollers are all going to take their proper radial position and cannot be thrown out.

John C. Bley, M. W. S. E.: I would like to ask how much of his gearing is cut-tooth and how much cast.

Mr. Carter: The back gear, motor pinion, and equalizer gears are cut. All the rest are cast. In another job of that size I would cut the bevel gear and the equalizing gear, but it is not necessary to cut the rest of them as they are mostly slow moving. In fact, the coefficient of friction soon went down, so that our rate of swing was too fast. The end of the bridge was going six miles an hour.

William B. Jackson, M. W. S. E.: Going back to the control of the motors. We have been told that the resistance melting is large. I have been wondering whether there has been any trouble with the motors themselves and whether, considering the fact that the resistance had burned out, there was not danger that the next thing that may occur is the burning out of the motors unless there is some automatic control of the flow of the current by contactors or some such arrangement.

Mr. Carter: There is an automatic control of the current on the switchboard by the overload circuit breaker, though that is set very high; but as a matter of fact, those motors have never warmed. They did not get warm at the time we burned out the resistances. They were not, at any time, so that you could not bear holding your hand on them, and I have seen motors under other duty where they got so hot they smoked, and even that did not break down the insulation of motors of the character we have here. Of course, an alternating current motor in its secondaries does build up an enormous current, especially if it gets stalled, and it is liable to generate considerable heat, but my experience has been it is the grids that give trouble. The first grids were put at the back of the switchboard. They burned the insulation on the wire. As the Willamette operating house has in it about $16,000 worth of machinery, it was too dangerous. So we immediately set them up outside. One of the men put his coat on top of the grid. We had a signal to open. The first thing we knew the coat was on fire.

The second set burned up. We now have a set, as I said, about three times the carrying capacity of those that were put in at first. My experience is that you cannot depend upon the electrical people to figure the electrical resistance for operating a bridge. They do

not consider that they are starting from a state of rest at maximum load.

Mr. Bley: I should like to ask if some of the strains on the rack pinion, which developed on the lower bearing of the rack pinion shaft, are not due to the lack of concentricity between the center bearing and the treads and rollers.

Mr. Carter: Yes.

Mr. Bley: That is, it is not due simply to the working pressure on the teeth, but it is due to the irregular radial pressure that comes in?

Mr. Carter: Yes. That is the reason the expense was incurred to make that rack central with the tread. In a later design we have now built we have reamed holes in struts connecting to the center casting, so that a shop centering is done to the center. We put in about eight angles connecting from the center casting to the tread in order to insure getting this truly central in the field.

Too often crews will go out and center the tread "by guess." There is very little attempt to make the outer tread central with the bridge center and you get into serious difficulties in the field.

In one case at South St. Paul we had bolts 2½ inches in diameter holding the main pinion bearing to the bracket. They kept breaking. I finally had a set made of tool steel, temper annealed or temper refined, with probably a tensile strength of something over 90,000 pounds, but they broke by the outpush of the pinions on the main rack. This rack was found to be ⅝-inch out of center, and was finally corrected by moving the whole bridge and center casting in center with the tread and rack. This was the only way it could be done.

Mr. Bley: I should like to ask what was the shape of the cup-leather that you used on the center bearing. Was it a U-cup or was it an L-shaped cup?

Mr. Carter: It was a single L-cup, but it was a failure. It would have been a great deal better if it had been a double cup—a U-cup. It did not work and I do not now think it could be made to work because there is no longitudinal motion through the packing to keep the joint in shape; and in reality it is not needed if the bearings are made to fit and carry all the oil grooves within ¾ of an inch of the outside of the lens. All the pressure needed is to get oil through the joint, and if you put pressure on it the oil has to go through the joint and it lifts high enough to do it.

Mr. Bley: I did not notice any oiling of the roller bearings. I mean oil-holes in the axles of the bearing wheels, through the shaft. Do you depend entirely on the three hub oil-holes?

Mr. Carter: Yes. We have a little recess in there. We get plenty of oil, as they do not require much.

Frederick G. Vent, M. W. S. E.: In regard to using tangential rods, I can relate a little experience in the La Crosse draw. We designed that without any tangential rods and I was there when we had a drum on the center and the rollers, and they moved the drum

around to see how it would work and every one of the radial rods took the shape of a letter S, and the pulleys were skewed very badly. It was necessary to put in tangential rods to remedy the difficulty. There was a spider on the center casting that fitted tight, and that stuck enough to cause the trouble described.

In regard to figuring machinery on the Clinton plant, we made some average readings a week before working up that machine rigging, and the loads, just as you say, ran up almost twice the average horsepower in a peak. The average text-books figure an average horse power just about half what you have to meet.

In regard to determined deflection sideways, did you make any figures on how much that would be on the Willamette draw?

Mr. Carter: No, we did not make any figures. It could be figured, but I do not know that it ever has. But we observed on the Wisconsin channel of the St. Louis Bay bridge, which was somewhat shorter than the Vancouver, and built on the same design, about 2⅜ inches side warp at both ends, which would be about 4¾ inches total from end to end. That bridge stands almost directly north and south and is not reversible.

Mr. Vent: How long is the span?

Mr. Carter: That is about 460 feet. That side warp was so bad it moved the track.

Mr. Vent: Double track or single?

Mr. Carter: Double track. One end is on masonry. The other end is on a false work piling.

Mr. Vent: On the Clinton bridge we figured about 50,000 pounds, possibly three inches side warp.

Mr. Carter: The worst feature about this side warp that has to be taken care of is, of course, a tremendous load that goes through the bottom lateral system to force a bridge straight when it is warped by temperature, and unless you calculate what that distortion is, I think you will be surprised to find the loads that go through the system that way. In a long bridge you will have about four inches to take out, or about two inches, we will say, either way from the center, and you have to distort that lower lateral system two inches at the end when the end is locked. If you can turn the bridge around the heat of the sun will take care of it and you will only have perhaps a half inch to take out of it.

Mr. Norwood: I want to ask Mr. Bley a question. A gentleman came in my office today with some specifications that called for mill motors, and he asked me, "Why do they specify mill motors?" Mr. Bley has made a number of tests on motors and I should like to have his view.

Mr. Bley: I do not know that I can answer that question in any definite way. We have not made any definite tests on motors and the only reason for using a mill motor that I ever heard was that somebody imagined it was fool-proof, that you could turn in an enormous amount of current without breaking it down or burning it out, and they thought if you put in a mill motor on a bridge you

would simply have fool-proof motors. Personally, I do not see the necessity for the expense. I think the railway motor answers all necessary purposes of bridge operation and we might just as well save the extra expense that the mill motor occasions. I used to feel that I wanted a motor mounted on springs in order to reduce the shock on gear-teeth from sudden starting, but the later practice of increasing the amount of controller resistance so that the first point on the controller is just about enough power to take up the back-lash of the gearing, has made spring suspension no longer necessary, as far as I can see, for ordinary service. There may be some other points to consider in favor of spring suspension, but on the score of shock, which was the reason why I was in favor of it originally, I think the day for spring suspension is passing.

I think that is about all I could say on the motor question. Generally we use the railway type of motor on our city bridges. In a few, or one or two of the later bridges we have used mill type, but I think the mill type was adopted, as I said before, because somebody imagined it was fool-proof.

Mr. Norwood: I will say that the introduction of the interpole has been one of the saving factors on DC 600-volt railway motors. The City of Chicago carries extra armatures for emergency installation and I think they have records showing that very few of the armatures have been used on motors having interpoles. Personally, if I am asked to give my opinion, I will say that the interpole motor on 600-volt service is satisfactory and it is not necessary to have the mill-type motor.

THE CITY MANAGER

A NEW OPPORTUNITY FOR ENGINEERS

By Gaylord C. Cummin.*

Presented May 15, 1916.

It is with a great deal of pleasure that I bring to you a new thought in public affairs which should interest you as citizens, and should be of peculiar interest to you as members of this body, because it has received its best expression to date through engineers, and promises in the future a wonderful opportunity for engineers to assume in the public mind the position to which they are justly entitled. Engineers have been entirely too content in the past to take credit only for their technical achievements, and leave the glories of dreams that come true, of wonders of administrative effort, of wise and judicial counsel which have made our country great, to rest on the brow of those who were in positions of prominence, and to whom they do not rightfully belong.

A real engineer is much more than a man who juggles with figures and formulae, and makes queer designs on a drawing board. A real engineer must know for what purpose he plans both economically and physically; he must know how his plans can become financially possible; in short he must be an administrator in order to make his designs accomplished facts, and to build efficiently and well. Very many engineers can do all these things, and yet are content with being employed only for their technical knowledge, whereas such qualifications as those above, equip them to take a leading position for public service in the community where they live.

In this field of public service the engineer has always taken a much more subordinate position than that to which he was entitled. Seventy-five per cent of the problems which occur in the administration of our cities are engineering problems pure and simple, and the rest of them are such that an engineer is at least as well fitted to handle as a man trained along any other line, they being largely problems of organization and social justice. The vital municipal problems are pure water and plenty of it, adequate sewers, clean streets, proper buildings, adequate transportation facilities, efficient police and fire protection, proper education and recreational facilities, etc.,—these things to be secured with the smallest expenditure of money possible to get the needed results.

Most of these are engineering problems and can be best handled by engineers; hence our opportunity once the citizens can be educated to the point where the administrative part of the government is judged on its ability as such, political questions being relegated to the legislative branch where they belong.

Municipal government in the United States has been unfortunate in both its genesis and its evolution. It is clear that advanced ideas and ideals of government are most likely to develop in comparatively

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*City Manager, Jackson, Mich.

small and coherent communities. In Europe the nations developed from cities, and national government from city government. Due to this development the cities of Germany and England have had a large measure of freedom, and abundant opportunity to develop what governmental forms were best suited to their peculiar needs. The result has been that the cities have been many years ahead of the nations of which they are a part, in government and in the effectiveness with which they render service to their people. In this country at the time our national government was formed, we had no cities properly speaking, and the simplest and crudest of methods sufficed to handle the municipal problems of the time. As the cities outgrew the possibilities of the old town-meeting and our cities became large and their problems complex, a change had to be made, and our national form of government was modified and used by the city, and without any reference to the reasons for certain provisions in our Constitution. The cities accepted both the fit and unfit, even to the two houses in the legislative branch. To further complicate matters in many cases a large number of the administrative heads were made elective, whereas in our National Government as outlined by the Constitution, *no* administrative officer was supposed to be elected, the President being selected and appointed by a deliberative body;—the electoral college. This is the basis of the so-called "federal form" of municipal government.

It consists briefly of a legislative branch of one or two houses, elected from districts called wards, an elected administrative officer called the Mayor, and elected administrative department heads *ad infinitum*. This form is distinguished by a system of checks and balances to insure honesty and prevent efficiency; by almost guaranteeing that no administrative head shall be selected for his fitness for his particular position; and by insuring that no man knows for what he is responsible, or to whom he is responsible. Furthermore, because the legislative branch and administrative officers are each severally responsible to the people, there is no teamwork in the organization and the real good of the city is sacrificed to petty political quarrels. The speaker was an officer in a government of this kind where the council was of one party and the administration was of another. Everything good started by the council was blocked by the administration and vice versa, the city very naturally suffering.

However, it is admitted that the federal form is not and never has been a success, so I shall not elaborate upon its shortcomings. Suffice it to say that it violates every fundamental of efficient organization.

The so-called "Commission" form as exemplified in Galveston and Des Moines is a decided improvement in some ways, but falls far short of the ideal. This plan consists in brief of a small council elected at large which constitutes the legislative body, each member being made the administrative head of one of the city departments. This is an improvement, because ward lines are eliminated and the organization somewhat simplified, but still has a lack of centralized

responsibility, places men in technical positions who are not specially qualified for them, and is positively vicious in making a man's success as a commissioner depend upon the success of his particular department and not the success of the city as a whole. This will result in time in a majority of the commission dividing the bulk of the funds among their departments, because in this way they can show more results, and the minority taking what is left, although their departments may be the most important. Under the commission form there is no fundamental improvement in organization, the improved results coming from an awakened public interest in municipal affairs shown by the fact that any change in government was made.

Now before we go further let us state a few fundamental facts that are often ignored in considering governmental affairs.

It is impossible to legislate honesty. This is attempted in our famous principle of "checks and balances," which does not prevent dishonesty but does prevent efficiency.

It is impossible to legislate efficiency, and no laws or charters will ever insure it.

The legislative branch of government is the real governing body, the policy forming body, while the administrative branch merely carries out these policies; and any attempt to mix the functions as here laid down will result in disaster.

A city is a business corporation, with citizens as stockholders who expect dividends of service. A city differs from other business corporations only in that, fortunately, its income does not depend upon its efficiency.

Now considering the city as a business proposition let us analyze the type of ogranization as set forth in the federal and commission forms in the light of this viewpoint.

Would any of you care to invest your money in a business whose stock was widely held and where the stockholders elected a board of directors, a president, a general manager, a superintendent, a chief chemist, a chief engineer, etc., none of whom were to be responsible to each other and whose fitness for technical administrative positions was subordinated to their being "good fellows," because the individual stockholder would be in no position to properly inform himself as to those technical qualifications?

Would you care to invest your money in a business where the stock was widely held and where the stockholders subject to the same limitations as before should elect a board of directors each one of which would *ex-officio* become general manager, auditor, chief engineer, etc?

If you did care to, your families would certainly be justified in worrying about your sanity, because such corporations would certainly end very quickly in a receiver's hands, and yet you are investing for your health, safety, comfort and welfare in just such corporations.

The Commission-Manager form of City Government is an exact parallel to the form which our experience has taught is the only one

under which satisfactory results can be obtained in business. It is not presented as bringing about a municipal millennium. Nor, is it new in principle—only in application. There are no mysterious or wonderworking powers concealed within it. It is simply the application to city government of the only methods by which we have been able to manage business corporations efficiently. It does not *insure* efficient government. No charter form can do that, but it is the only form under which efficient government can be expected, judging by our experience in business.

It consists briefly of a small council elected at large, corresponding to a board of directors and whose duties are purely legislative. This body appoints the chief administrative officer, the City Manager, who corresponds to the general manager of a corporation, and who has complete control of the whole administrative machinery. He holds office at the pleasure of the Commission and is responsible to it for his acts. Responsibility is absolutely centralized on the Commission and through them on the Manager.

There is never any chance to dodge an issue by placing the blame on somebody else. If anything goes wrong in the administrative branch the Manager can be held responsible and the people can call their representatives to strict account for mistakes and inefficiency in the administrative branch, because of the Commission's power to remove at will the City Manager.

What has been the result of this mode of operation? In the City Manager cities party politics has been entirely eliminated from the administrative side of city affairs. In our city the Commisson do not know my poltics and I do not know those of a single one of my subordinates, and, furthermore, I do not care. A man's beliefs on the tariff or our Mexican policy have no bearing upon his efficiency as a Water Works Superintendent. What possible difference does it make whether the dog-catcher is a democrat, republican or socialist, providing he is a good dog-catcher?

We have teamwork in our organization and nothing can be accomplished without that. We must have it because the department head that refuses to work in harmony with the manager will soon be looking for another job, and the manager who will not work with his commission will not last very long.

Our department heads are selected for special fitness for the positions which they hold, and not because they are "good fellows." The manager must select on this basis because an inefficient department head will reflect on the manager and he cannot evade his responsibility.

Responsibility is centralized from top to bottom and this is the best incentive to honesty and efficiency that has yet been devised.

Our accomplishments in Jackson after one year's operation are as follows: We have taken city employes out of politics, reorganized the police force, and are developing it on the basis of a survey of its needs made by an expert in police organization; are using a trained social worker as policewoman to handle the young girl problem;

have installed a modern system of double accounting with controlling accounts; have passed our annual budget based on a uniform classification of expenditure by kind; have installed careful cost accounting on city construction work, separated the sinking fund from the general fund and put it to work, accumulated a sinking fund balance of $45,000 where the old government had none, centralized the water department under a competent superintendent, read meters quarterly instead of semi-annually, presented bills to consumers as does any like public utility. We have divided the city into three sections, so that the same force of meter readers can be employed constantly, the bills for one section being due each month; have made a waste water survey; and are reinforcing the much neglected distribution system on a rational basis. We make purchases for the city through a purchasing agent and take all cash discounts, these amounting to enough to pay all the expenses of the purchasing agent and his office. We have replaced $380,000 on the tax rolls that was formerly exempt without legal reason; and made all assessments both for taxes and special purposes under one man on full time instead of nine elected assessors on part time, at a saving in cost and increase in efficiency. We are saving $4,000 per year by paying the treasurer a salary instead of fees. We are making a complete study of the very inadequate sewer system, based on a topographic map now being made on a scale of 1-inch equals 200 feet and with a 1 foot contour interval, and are contemplating a complete re-design on modern lines with a comprehensive plan for relief as well as for future extensions. We have installed a modern boulevard lighting system under a peculiarly advantageous contract; installed patrol system of repair on graveled streets; are giving efficient food and milk inspection; have replaced a part-time health officer with a competent physician on full time, made over twice as many inspections with one sanitary inspector as were made formerly by two; have centralized privately supported public nurses, the organized charities of the city, the city poor relief and humane officer under a trained social worker so that there is no duplication of work; we have made the city hospital and training school for nurses a model in so far as the buildings will allow; will construct this year a modern hospital building to cost $150,000; have equipped and opened a tuberculosis hospital; equipped and opened two branch libraries; started the improvements on a new 520-acre park; are motorizing the fire department on a plan that will make it unnecessary to purchase any new horses or sell any horses at the height of their usefulness; are completing a building code; are giving efficient electrical inspection, and have inaugurated inspection of weights and measures.

We have reduced the net debt over $50,000, paid off a floating indebtedness of over $20,000, given over $15,000 services not contemplated and ended the fiscal year with a cash balance of nearly $10,000 and liquid accounts receivable of $37,000, and have not raised the tax rate. Furthermore, although theoretically we operate

for six months on borrowed money, and heretofore money was borrowed seven to eight months before receipt of taxes, we are now in our fifth month and have not borrowed a cent.

Any city can get as good results by using a few business methods and a little business sense. I am not detailing these things for any other purpose than to show the possibilities of this mode of operation, and to give you gentlemen a slight idea of the diversity of questions that come before a city manager. I have the administration of such unusual things as a public library, two hospitals, two cemeteries and a small summer resort.

The special point of interest to engineers is that all the larger cities operating under this form of government have engineers as city managers and they are making good. In fact, in many cases none but engineers are being considered. A city manager must be primarily an executive, but given that qualification the engineer is preferred over men of other professions, because such a large percentage of the problems which arise are engineering problems.

There are now over eighty cities and towns operating under this plan and the number is just about doubling each year. Where are we to find the city managers for these openings? Most of them will be drawn from the engineering profession direct, for a good many years, but finally we hope that the plan will spread so that a man can take it up as a profession, start as manager of a small town after having received an engineering education, and be promoted to larger ones if he makes good.

In this field there will be in the near future many openings for engineers, well paid permanent positions, where the engineer can at last take his proper place in public service to the lasting benefit of both engineer and citizen.

DISCUSSION.

President Grant: What is the population of Jackson, Mr. Cummin?

Mr. Cummin: A little over 40,000.

President Grant: The catalog of the things which have been accomplished by Mr. Cummin in one year is rather remarkable. It seems to me besides being an engineer the manager needs to be a great many other things. One thing seems to be that he needs to be a financier, judging by the figures that have been quoted.

*W. F. Smit*h ASSOC. W.S.E.: I would like to ask the duration of time through which these commissioners and the manager hold office.

Mr. Cummin: The manager is not appointed for a specified term. He holds at the pleasure of the commission, absolutely. Our commissioners are elected for four-year terms alternately, two at a time, and the mayor is the chairman of the commission and is elected every two years. So it would be possible to change the complexion of the commission in two years.

Mr. Smith: How long does the manager hold office?

Mr. Cummin: As long as they want him. The present commission could ask me to resign tomorrow if they wished.

President Grant: In how many states is the city management form now possible?

Mr. Cummin: It is possible in California, Oregon, Arizona, Texas, Michigan, Ohio, New York, South Carolina and North Carolina.

President Grant: What is the largest city that is under that form of government?

Mr. Cummin: Dayton, Ohio, with 140,000 population. They have done wonderful things in Dayton, much more wonderful than we have been able to do. They had a much more difficult problem to work with there. They had a large floating deficit and were burdened with a tax law which made it almost impossible to straighten themselves out. It was like running a corporation which was on the verge of bankruptcy. They have had a rather hard struggle, but they are the only city I know of in Ohio that is living within their income under that tax law. Cleveland is behind $800,000 I understand.

J. W. Lowell, ASSOC. W. S. E.: Just what legislation and procedure is necessary to inaugurate the commission form of government?

Mr. Cummin: In most cases they operate under a constitutional amendment giving home rule to the cities. In New York state they operate under optional charters. They have three optional charters which any city can elect to adopt. In most of the home rule states the electors have to petition for a charter election to be held, and at the time of the election they vote on the charter commission. Those charter commissioners draw up the charter in real home rule states and that is submitted for their acceptance.

H. L. Kellogg, M. W. S. E.: In those states in which a commission form of government is possible can the commissioners when they are elected choose the manager?

Mr. Cummin: They possibly might under some charters, but that would probably be unsatisfactory because the powers of the manager would not be clear. One of the difficulties that has been discovered in a number of towns is that the commissioners find it hard to realize just what their power should be. Their power should be purely legislative and they insist on interfering with administrative affairs. Sandusky has had quite a struggle on that question. The commission insisted on making certain appointments, and the city manager tolerated the conditions for about a month and then he made a stand and said he was going to do the employing. They are still fighting about that.

W. S. Lacher, ASSOC. W. S. E.: The success of this plan, the same as any other, depends upon the freedom of the manager to act?

Mr. Cummin: Yes.

Mr. Lacher: Is there anything to prevent the commissioners from trading with a candidate for the position of manager before he is appointed?

Mr. Cummin: Under this form, when things go wrong you cannot place the blame on somebody else, and as long as the city is efficiently governed I do not know that it makes very much difference if they do arrange beforehand with the manager. If it is not efficiently governed, they will not last long, because all those charters provide for recall. You see the legislative branch cannot lay the blame on the administrative branch, and vice versa. In the federal form of government, if things go wrong the council can say it is the mayor's fault, and the mayor can say it is the council's fault, and you do not know who is responsible.

Mr. Lacher: As I see it, the commissioners can make the position of manager simply a figurehead or require of him that he give them the patronage of his office. Would that not simply reduce this form of government exactly to the commission form as it now exists in some places, that is, the city manager would be a mere figurehead?

Mr. Cummin: Yes, absolutely; but inefficient operation will result and the recall can be put in operation.

President Grant: How old is the oldest city manager government?

Mr. Cummin: Staunton, Virginia, is really the first one, but the first one of any size in Dayton. Dayton has been under this form of government since January 1, 1914.

President Grant: It is a comparatively new thing, then?

Mr. Cummin: Yes, in this country.

President Grant: And is it not a fact that the commission form of government has failed to accomplish its purpose in some cases?

Mr. Cummin: Yes; as I pointed out in this paper, it has fundamental weaknesses that are bound to show. You really have made no improvement in organization. You still have a headless affair. You have five men who are not responsible to each other at all and they have administrative duties. Now, you cannot do that in business and you cannot do it in a city. If you had in a business a general manager and a superintendent and a chief engineer, and they were not responsible to each other at all, I do not think you would get much team work in that organization. You would get inefficient management. You could not help it.

E. N. Layfield, M. W. S. E.: I should like to ask how the idea took root and grew that an engineer should be the city manager rather than a politician, or, if not a politician, a so-called business man, or perhaps a lawyer. I think, naturally, that the engineer is the best executive, but I am puzzled as to how it was possible to convince the voters and politicians so that this thing could take root and become an actual thing, as it has done.

Mr. Cummin: You did not have to convince the whole electorate. You had only to convince five men. If they were at all conscientious, just as soon as they started looking into the thing, they discovered very quickly that what they needed was an engineer.

Mr. Layfield: Was not that because they had the example before them of some particularly efficient city engineer, so that they

saw that certain city engineers handled things differently from the ordinary lawyer or business man who was appointed to a position of that kind?

Mr. Cummin: I think it was largely because they realized that most of the city problems were engineering problems and the engineer has an advantage, because the business man, for instance, must take the word of somebody else for the technical part of it. The engineer can work into the things that he does not know anything about, which are purely matters of organization, but the business man cannot get a working knowledge of the technical end. That is the reason an engineer stands in a better position as a city manager.

A Member: Have any cities which have adopted this new form of government gone back to the old?

Mr. Cummin: None that have a charter organization. I believe one of the small towns on the North Shore went back, but that was an ordinance organization and that is almost impossible to operate because the manager has no powers; that is, he has no definitely fixed powers.

A Member: It seems to me that the first city manager would have a good many obstacles to overcome on account of the old politicians. He would have to be quite a diplomat.

Mr. Cummin: You do have trouble with them, but there are some things the average politician does not understand, and just as soon as you start to using those you have him at a disadvantage. For instance, when he finds out that you say just exactly what you mean and you do treat everybody alike, whether they are your friends or foes, he does not know how to act. We have some of them considerably puzzled. They come up and we treat them like everybody else. They are surprised that we are not vindictive toward them.

F. H. Cenfield, ASSOC. W. S. E.: I am very much interested in city management work throughout the country and have read a great deal of what various city managers have accomplished. It may be interesting to those present tonight to know that even Chicago has taken steps towards the city manager form of government. Not under that name exactly, but very recently a resolution was offered in the city council and referred to the council judiciary committee, which contemplated dividing the city into fifty districts, having one representative from each district to make up the common council, instead of having two representatives from each of thirty-five wards, as at present; this plan also contemplates that the common council shall elect the chief executive instead of choosing him at a general city election, as at present. I do not know what will become of this plan, but it is an indication of what is coming, even in Chicago, a city of approximately 2,500,000 people. It is the kind of government that all large corporations of the country have. A corporation which is responsible for spending eighty or ninety

million dollars a year efficiently has a big task on its hands and it needs the best men available.

One of the troubles of municipal government is the frequent change of administrative heads. It is believed that we should have the same principles applied to municipal government as to tenure of office as is applied in the administration of a private corporation. Retention in a position should be based purely upon ability to perform the duties effectively.

As I heard the speaker describing the powers of the city manager in choosing his assistants, I wondered what the attitude of the people had been towards the selection of assistants from other cities. In many places there is a feeling against bringing in outsiders who have not contributed towards the revenue of the city. Unquestionably, administrative heads can be found locally, but there is no doubt that the choosing of expert administrative heads from any part of the country would do much to improve conditions.

There is another question I would like to ask the speaker, and that is regarding employment control. The problem probably would not be very difficult in a smaller city, but in a larger city where the number of employes amounts to possibly 20,000, and where there is a great diversity of activities it would appear that there should be some disinterested employment body to save the chief executive and the administrative heads from any possible interference and trouble in the selection of subordinates.

Mr. Cummin: I think there should be some control, not only for that purpose, but because it would simplify his whole employment problem very decidedly. It should be very difficult to get in and very easy to get out, which is one of the things which the usual civil service law does not accomplish. In my own case, I do not act as employing officer. I have the power, but I make my department heads responsible for their own appointments. They pick out their own men. I do not even want to see them. I hold those department heads responsible for the work under them. I cannot hold them responsible if I pick out their tools for them. For instance, the chief of police ought to know a good deal better who would make a good policeman than I would. So the chief of police appoints the policemen. Of course, I legally do the appointing, but he comes in when he has a vacancy—he has had a few during the last six or seven months, about one-third of the force—and he says he wants to appoint So-and-So as a policeman. I say, "All right. Go ahead." I send his name in to the accounting department as being on the payroll. I never see him until he gets out in uniform. Of course, if the chief of police makes a poor appointment there is trouble. But what I have told the department heads is, that as long as they are running the department they must run it, and when they get to the point where they cannot run it, I will get some one who can.

As far as bringing men from outside the town is concerned, there is a feeling against it. I do not think it is very strong in

Jackson, but there is a feeling among certain people, and that also brings up the question of political patronage. The people have to get new ideas of public service and the public as an employer. I do not consider that I am doing any man a favor by giving him a position in the City of Jackson. I hire him because he will pay the city dividends. I do not figure that the city of Jackson is doing me any favor by hiring me. If I cannot earn my salary and more I ought to be replaced at once. The people should realize, and they are coming to realize, that public positions are not a matter of political patronage at all. A public position is a place where you put a man because he can do the work. As soon as the people come to that way of thinking it makes no difference where you get the men to fill the positions.

It is exactly the same proposition as in any other business. A man is hired because he can pay dividends on his salary. There is no fundamental difference. As soon as you get on the administrative side of the city, as I have said before, the only difference between it and a business corporation is that very fortunately for the city, its income does not depend upon its efficiency. Most cities would have been in bankruptcy long ago if that had been true.

J. N. Hatch, M. W. S. E.: I would like to ask something about the arranging of the finances under that form of government. I presume that there is a budget arrangement.

Mr. Cummin: Yes.

Mr. Hatch: In whose hands is this budget, and how is it distributed to the heads of departments? That is, what I would like to know is, if you are given a certain budget at the beginning of the year and have control of that, and how and to whom you report expenditures or the proposed expenditures.

Mr. Cummin: They are furnished with a uniform classification for all accounts by kind. They are furnished with a sheet which details under those particular headings just what they spent the previous year. They are asked for their estimate for the coming year, and they have to defend every item before the city manager. If there are any large increases or decreases they must show why they are needed—not what they had appropriated the last year, but what they spent in the last year. On that sheet their new estimate goes right alongside of it under exactly the same classification. They have an absolute comparison. You know they have not hidden anything away some place and you know the same code number means the same thing this year that it did last year. We have none of those accounts that are such a relief to the ordinary man, "contingent fund," "miscellaneous," etc. Everything they ask for is shown under a definite heading and it is asked for in a parallel column with what they asked the year before under that heading. That all goes to the manager. Of course, it goes from the minor officers to the department heads and they revise it and then it goes to the manager, and they have to defend their case with him. When it is completed

he recommends the budget to the commission for passage, and they pass it or not, as they think proper.

President Grant: Is there any law in Michigan as to the uniformity of municipal accounting?

Mr. Cummin: No.

President Grant: Wisconsin has something of that kind, has it not?

Mr. Cummin: Yes, so has Ohio; but the probability is that with all those systems the most you can do is to get a uniform system of reporting. Our states are so large and conditions are so diverse that you are likely, in trying to establish a uniform system of accounting, to get something hard to operate. I think it would be a mistake. In fact, the way it works out is a uniform system of reports. Ohio has that and they have some very fine systems of municipal accounting in the state of Ohio.

The usual administrative branch of the city looks upon the accounting department as a necessary evil, and they pay just as little attention to it as possible. How an administrator can run a business of that size without an efficient accounting system I do not know. I cannot. I need to have that information that an accounting system can give in order to know what I am doing. The average municipal accounting system is the cause of much of their trouble, because it is a system that the corner grocer discarded thirty years ago. Every new man that came in as the head of a department—he might be the butcher, the baker or the candlestick maker—he did just what his predecessor did, and if he thought he saw a short cut he took it. The consequence was your accounting systems became progressively worse.

If you desire an instance of that, look at the annual reports of almost any municipally owned public utility and see how many things they have left out. I know of one that reports arc lights at a cost of $25.21, but in reading the report carefully it is seen that they have left out all fixed charges on their distribution system and many other things.

I remember another case in which I had occasion to investigate a garbage reduction plant which seemed to be making a very remarkable record, and I happened to know the plant had cost considerably more than it should have cost. I found that all they were charging against it was purely operating payroll expense, omitting not only capital account, but even materials used in operation. With their fixed charges included instead of showing a large profit, they showed a large deficit.

I do not know anything about the accounting system in Chicago, but most of the accounting systems, from that of a small village where the books consist of a bank book and check book which the mayor carries around in his pocket, up to those of large cities, give no information. I get a balance sheet every month, I get a statement of receipts, and I also get a segregated statement of expenditures all the way through. I know from that report what my de-

partment heads spent for postage stamps. I do not see how any executive head knows what is going on without it. I look upon an accounting system not as a necessary evil, but as a matter of necessity.

N. M. Steinman, ASSOC. W. S. E.: I have in mind a small town with a fixed population of about 2,800. It is a college town, and in addition to the 2,800 there are 1,000 or 1,200 students, so that the population might be called a little less than 4,000. Its government is organized under the usual old form. There is a mayor given $300 a year, councilmen given $100 a year each, a village treasurer, a clerk, an attorney who is given a small sum, and a surveyor who is given his fees. All of these are more or less nominal salaries, but when you add up the salaries of all these officials you will find they amount to several thousand dollars a year. One of the worst troubles of this town is the question of electric light. There is a municipal electric light plant, and I think most of us realize that in a communinty of that size the market is not large enough for an electric light plant. The machinery is obsolete, the equipment is obsolete, and the people in that town are paying perhaps several times as much for electric light as we do in the city of Chicago. The waterworks is also a big problem. The town cannot afford to have an efficient waterworks superintendent or an efficient electrical engineer to operate the electric light plant. It has often seemed to me that the solution of the town's troubles is the city manager plan, with a city manager who is also an electrical engineer. Now I do not intend to apply for the position as city manager of that town, because I am not an electrical engineer, but I would like to ask Mr. Cummin this question: Does he think that a community of that size is large enough to support an organization such as a city manager would need to have? I take it for granted that there is a limit below which a town or community would be too small to support such an organization.

Mr. Cummin: I think so. They could certainly improve their present situation very materially, though, of course, there is a vanishing point below which you could not get a man who was reasonably efficient.

You start looking into the cities and you will find there are a lot of ridiculous things in the way the departments are organized. Of course, the engineering department usually suffers because they cannot play politics so much with the engineering department. A man in that department has to know something. But in Jackson, when I took hold I found the engineering department to consist of the City Engineer, one instrument man and one rodman, to do the engineering for a city of 40,000 people.

They had a fairly good man as City Engineer, but they would not give him anything to work with. He tried to get an assistant, but they would not let him have one. I have twelve men in that department now and they are all working to good advantage.

Some of the objectors pointed out that it would be a very ex-

pensive way to run a government. So we took our complete salary payroll and compared it with the one of the year before. We were spending $1,500 more. This included two policemen, which were, of course, routine increases. They forgot the useless offices we lopped off.

A Member: Just what is the relation between the city manager and the legal department, in connection with special assessment work, and such matters?

Mr. Cummin: The legal departments are in exactly the same position as they would be in a corporation with a legal department. The legal department is always a thorn in the side of a man who is trying to do anything. There is no difference in this case. They will say, "No, you can't do that," and you can't do it. There is no argument. It would not make any difference whether he was absolutely under the manager or whether he was not.

A Member: Is the legal department under the city manager?

Mr. Cummin: Sometimes it is under the city manager and sometimes it is not. I mean, sometimes it is attached to the city manager and sometimes it is not. In this particular case I do not see that it makes very much difference which it is. It acts purely in an advisory capacity.

So far as special assessments are concerned, the matter of putting the actual assessments on the rolls is done by the commission. The commission orders that a certain improvement should be made. They pass the necessary legislation for the improvement, and the assessments are then made by the city assessor, submitted to the commission and passed.

A Member: Then they proceed just the same as the old form?

Mr. Cummin: That is a legislative act. The legislative body hold the purse strings always, which they should do.

The Member: Does that do away with the Board of Local Improvements?

Mr. Cummin: Yes. We have lost all our boards, even the library board. The librarian went to a meeting of the American Library Association and reported that he had no library board, and he said they acted as if it was positively immoral. We have gotten along very nicely. If something is necessary to be done at the library they do not have to wait a month; they report to me. Ninety-five per cent of the matters that go up to a library board are routine matters that the librarian knows much more about than the board, and the other five per cent consists of matters of policy which any-one else can decide fully as well as a special board. Nearly every board that has power to do anything is always managed by one man; so what is the use of having any others on the board? It has been said that the ideal committee is a committee of three, one of which is out of town and another in bed with a broken leg. That is about true. A board is very good if it is purely advisory, but just as soon as you give it administrative functions it takes three times as long to do a thing as it takes one man.

L. L. Holladay: What can the engineering societies do to promote the city manager idea?

Mr. Cummin: The whole thing rests on certain fundamental ideas that the citizens must get in their minds, which they will eventually. They are getting them, but it requires a campaign of education. They must get it out of their minds that you can legislate honesty and that you can legislate efficiency, and that if efficiency in city government is expected, the tools must be supplied with which to get efficiency.

Mr. Layfield: I would like to answer Mr. Holladay that one of the things an engineering society can do to promote this thing is to get a man like Mr. Cummin to come here to tell us about his work; and we, of course, intend to publish in our Journal what he has said so it will be distributed over the world.

Mr. Cummin: It is absolutely a matter of education. As soon as people realize that the legislative is the governing body and that the administrative simply carries out the orders of the legislative branch and that the results they are looking for is service, they are going to judge the administrative part of the city by what it gives in the way of service.

J. L. Jacobs: The remark made by the previous speaker on the difficulties which must ofttimes be overcome where the administration of affairs is dependent on joint action of a board instead of a single head is very apt. I recall an experience where a board, consisting of more than three members, refused for personal reasons to act on an important administrative matter. For a long time this important work was held up and its efficiency decreased and final cost increased. This board was hopelessly split. Being, partly at least, made of wood, mending was made particularly difficult.

I have been much interested in the paper read by Mr. Cummin. The facts brought out of the increasing opportunities for engineers and other trained men and women as administrators of public affairs, in the city manager cities particularly, and of the efficient and responsible administration which is being obtained in cities working under this new plan, are indeed enlightening and suggestive.

Under the city manager form of government accepted business principles are being applied in running municipal affairs. The city manager form is popular with the business men as well as with the average person who has been engaged in large organizations or in the public service. The principle of fixed responsibility for administration of affairs to bring about efficiency and economy and effective service is not a new one. There is no mystery attached to it. Private corporations and organizations have been working under this principle for years. The most successful have recognized the necessity for centralized authority and administration of problems by men who are not only conscientious and loyal, but are trained and expert in the work to which they are assigned.

The principle of home rule, of freedom of our municipalities to legislate and administer local affairs in accordance with the wishes

of the people, is inherent in the city manager plan. I do not believe that these are panaceas which will solve all the troubles and ills found in public administration, but I do believe that with these and with the enlightened interest and co-operation of the citizen-body, government and public service will continue to improve.

The point raised by Mr. Cummin with reference to the procedure used in drawing up estimates, the preparation of the annual budget and the passage of appropriations in the city in which he is city manager is interesting. While appropriations for municipal activities in a city of 30,000 or 40,000 citizens are small compared to those of a city such as Chicago, the principles involved in the preparation of estimates, making appropriations and controlling expenditures are the same.

There is great danger in preparing estimates and passing appropriations for an activity or a service on the basis of work done the year before. Estimates and appropriations should be drawn up with definite and complete work programs which should be supported by cost unit schedules. Control and responsibility for expenditures and service should be placed upon the administrative officers, who through the legislative body, are accountable to the electorate. The larger municipalities and some of the state governments are making advances in the form and procedure of estimate and budget preparation, in the passage of appropriation bills and in the manner of controlling expenditures. Lump sum appropriations, in which there is neither control nor responsibility for expenditures, are being superceded by the detailed or segregated budget, which furnishes some means of controlling expenditures. To offer greater freedom and fix responsibility on administrators and yet retain control over expenditures, segregated appropriation bills are being supplanted by the functional cost data and definite work program budget. Through these, better means are offered to hold officials accountable for the character and cost of service, expenditures for individual items are under control and responsibility is fixed.

In this connection it is of interest to develop the point touched on by Mr. Cummin concerning the need and usefulness of proper and sufficient publicity on work done and services rendered by municipal departments. The preparation of voluminous documents with complicated tables and other unimportant matter is wasteful and the publicity and educational returns therefrom are the inverse of the cost and efforts expended. Until our public documents and administrative reports generally are drawn up in brief, readable form, the maximum return of public favor for accomplishments and services rendered will not be forthcoming. The average citizen cannot become interested and look forward to the reading of public documents, as he does other matters affecting his welfare, unless they are placed before him in more interesting and readable form.

The statement such as made by Mr. Cummin of the accomplishments during the first year under the city manager form in Jackson,

would be illuminating and interesting and would do a great deal to bring to the support of the commissioners and city manager a large number of doubting and uninformed citizens. Publicity of public affairs is essential for effective and continuous good government. The engineer should keep this continually in mind when he enters the public service. The people will not continue to support even the most efficient, unless they are regularly and impressively informed of accomplishments and assured that results are commensurate with costs.

There is another point which Mr. Cummin touched on lightly in his paper, viz.: the method of appointing and retiring public employes. Until such time as the administration of public affairs is absolutely divorced from politics and appointment and promotion and retention of employes are based on fitness and ability and loyalty to service, it will be necessary to have some positive means of controlling public employment and preventing spoils dickering. To accomplish these it is essential that entry, promotion and retention of public employes be closely and fairly guarded.

In the Chicago city service it has been the aim to give the employes equal opportunities to enter and obtain promotion and assurance against dismissal except after full hearing before an unbiased board. This has resulted, I believe, in recruiting and retaining a better and higher type of public servant, in obtaining a higher standard of administration and in more effective and economical public service. The negative means which have been used for a number of years in the federal, state and many city civil services, *i. e.,* the civil service system of preventing spoils, are being supplanted by definite, positive methods of effective employment control. The adoption of these positive principles of standardization of employment, provision for advancement on seniority and efficiency, promotion on capacity and efficiency and general control over retention, retirement and discharge have proven successful and are being adopted by an increasing number of municipalities and other governmental bodies.

Mr. Cummin: There are a few points I might enlarge on.

I think Mr. Jacobs probably misunderstood my slight sketch of the budget procedure. We have no lump sum at all. We divide into the functions and under those it is according to this uniform classification of expenditure by kind all the way down, so that every item is a definite item and absolutely comparable from year to year.

As far as civil service is concerned, with the tight back door, taken as a general proposition, I mean taken in the broader view of it and not simply looking at it for one year, it is a very fine illustration of a great tendency on the part of the American people in government affairs. They try to legislate things which you cannot do by legislation. Any of you who have operated an organization know that occasionally you will run across a type of a man who is absolutely disrupting everything you are trying to do, and yet there is not one single thing on which you could base a definite

charge against him. That is where civil service with a tight back door fails. What you need is practically the same thing that you would have in the employment office of a big corporation. See that a man has the qualifications he should have before he gets in and then make it hard for him to stay after he gets in. Make it so that he must "deliver the goods," every day, or leave.

The point of promoting men inside the organization, of course, is a good one, but it is a fundamental law of organization. Anybody who knows anything about operating an organization efficiently knows if you have a good position open in the organization, if you have a man in the organization who can fill it, you should promote him to it, because just as soon as you remove the incentive to a man to work his way up, you decrease his value.

Mr. Smith: I would like to find out just what steps are to be taken when any new public proposition is needed, such as that hospital. Who determined that you needed a new hospital and whether they should build it or not?

Mr. Cummin: There are two ways in which that can be initiated. It can be initiated by the commission or it can be initiated through your administrative side. The commission may have some policy that they wish to see in force. That is, they may wish to build a hospital. On the other hand, the man who is responsible for the operation of the hospital may have discovered that the hospital is inefficient and expensive to operate and he may be able to convince the manager of that. The manager then initiates the proposition before the commission. That is what happened in this case. The health officer brought the matter up and we proved to the commission that a new hospital was a necessity, and then they passed the necessary legislation. We did not have any long-winded resolutions or anything of that kind. I just got the commission together and said, "Here, we must have a new hospital. It is impossible to operate except at excessive cost. The present one is not fireproof and it is much too small for our present needs. Now we can afford to build a new hospital."

Mr. Smith: Then did they have to refer it to the voters or do they have the power?

Mr. Cummin: In Michigan we have to refer any bond issue to the voters. We referred it to them and told them why. We had no trouble to pass it.

Mr. Layfield: Mr. Cummin, do you think that there is any fundamental difference between a small city of the size of Jackson and a large city the size of Chicago that would make any difference as to whether such a system, that works in smaller places, would work here or not?

Mr. Cummin: No. There is no fundamental difference. There is this difference: The results will be obtained much more slowly, but the executive at the head of the city of Chicago probably would not have as hard a time as I have, just as I do not have as hard a time as the man who is city manager in a town of 10,000,

because it is purely a matter of building up your organization and subdividing and subdividing and subdividing, and it does not make any difference how big it is. The Standard Oil Company is run by one man and the New York Central lines by one man. They have one executive head. It is purely a matter of subdivision below that. It would be easier for me with a population of 60,000. I would have fewer men reporting to me. I cannot afford to have enough overhead to reduce the men reporting directly to me to what they should be reduced. I have about nine reporting to me. I could cut them down to five if I had a city of 60,000, but I cannot afford the overhead, so I have more detail coming to me than I would have if I had a larger city.

Mr. Layfield: That answers the question as to the administration. Now, from your observation of the trend of this movement, do you think that it is likely to be feasible within our lifetime to convince the people of cities the size of Chicago that that would be the proper thing for them to do? Is it trending that way strongly enough to make it a reasonable hope that we could have such a thing here within the time we expect to live?

Mr. Cummin: I think it is. The president of the council of the city of Boston is advocating it openly for the city of Boston in every speech he makes as the only solution of the difficulty. It will take longer in the large cities. As the body of citizens becomes larger it takes longer to get any particular idea to them.

I think the point is that your large body of men is inherently conservative. The smaller the body of men the easier it is to get them to change. They do not get the personal touch they do in the smaller towns and it will take longer to get the large cities to do it. It will take longer to get results in the large cities. Your organization is more complex. It takes longer to build it up. It takes a great deal of time to build it up. For instance, you could tear your police department to pieces and stick it together within a year and have it going. The average police department in the average city has a good deal of trouble and they are blamed for many things they are not responsible for. In the city of Jackson it was absolutely true there were a number of people that the police force did not dare arrest. That is not true any more and they know it. The consequence is there has been a large increase of arrests and a much better spirit in the police department. They know if they get anybody they should there is no use going further up. They also know if they catch the manager speeding his automobile and do not arrest him and the manager finds out about it, there is going to be a vacancy in the police force. There isn't anybody exempt in the city of Jackson.

There were some people they did not dare arrest and others the courts would turn loose, possibly, just because they were somebody.

Mr. Layfield: How do you control the question of judges letting them off after they are arrested?

Mr. Cummin: By moral suasion. The judges, of course, I do

not control. The courts I have nothing to do with. But, nevertheless, by going to the judge and inviting him to help me out on some proposition, I can accomplish something. For instance, I want to stop automobile speeding. I go to the judge. He has been fining them $1.35. Of course, that simply encourages them. In this particular case I went to the judge and told him I wanted to stop this speeding and wanted him to help me out. He is a good fellow, not particularly strenuous, and he said, "Sure. What do you want?" I said I had heard of a system of fines by which for the first offense they were fined $10 and a dollar a mile for every mile they were going over the limit; second offense, $25 and two dollars for every mile over the limit; third offense, thirty days in jail. He said he thought that sounded like a good solution, and so we started out the next day and got about fifteen. We fined them sums varying from $18 to $25 apiece. It was a terrible blow. I got six or eight prominent citizens who had always had more or less their own way. They came to me about it, but got no consolation. Since then there has been a noticeable diminution of speeding on the streets of Jackson.

In the same way we had trouble with boys eighteen and nineteen years old loitering on the streets. The judge used to give them a talking too. I talked him out of that. He has been sending them to the house of correction. The last one got sixty-five days. He is cured.

Some other things that came up I just suggested to the judge that we wanted to stop and he stopped them.

A Member: I would like to ask Mr. Cummin's opinion as to the matter of the election of commissioners. Is it better to elect by districts, as the scheme has been proposed for Chicago, that is, enlarging the wards, you might say, or electing at large for the whole city?

Mr. Cummin: In a city of this size I would suggest electing at large and appointing from the districts. There is a decided difference. The point was best illustrated to me, I think, by an old Irishman who was somewhat under the influence of liquor. It was the time the city manager form was being agitated and he was quite an old ex-politician. I met him one night on the street and I asked him what he thought about it. "Well," he said, "I was against it at the beginning." (I can't imitate his brogue so I won't attempt to.) But he said, "In the Tenth Ward we have been wanting a great big storm sewer for a long time. It is necessary to drain that ward and our councilmen have been fighting for that for the last five years, and the other wards voted it down." We had twelve wards in the city. He said, "I have just realized that I haven't a voice in the affairs of the city at all. I only have one-twelfth of a voice. I can vote for the fellow who is working for us, but I cannot vote against the man who is working against us. I am disfranchised."

That is just what you would have in Chicago. You would have a fifty-second of a vote, but if you elect at large and appoint the districts you get away from that.

Mr. Layfield: In regard to the matter of getting the judge to do so-and-so in the case of an arrest, it seems to me that is largely a question of the city manager being able to dominate the other man. I do not mean dominate in an improper sense, but I mean the city manager must be a stronger man. Does not that really get back to the old proposition that the best form of government is a despotism if you have the right kind of a man for a despot?

Mr. Cummin: Of course, there is no question about that theoretically. But the whole point is this: That any man who is running anything has to know how to talk to people. Now, that man, the judge, means well so you can put the matter to him that way. If he were another kind, if he were not inclined to co-operate in any way, then publicity is the weapon. When he turned a lot of speeders loose with $1.35 fines I would proceed to see that everybody knew he did it, and I think that I could discourage him.

There is one thing I want to bring out, that the city manager plan is not a lazy man's government—getting something without doing anything. In the last analysis it goes back to the election of a good commssion. You will never get good government any other way. The only point is this way you have somebody to hold responsible. If my commission hampered me all the time I could not do anything. I can do things because they stick strictly to their legal duties. Of course, they knew the people of the city and I did not know them and when I had appointments to make I asked them about a good many men. They gave me their opinions, but they did not tell me whom they thought ought to be appointed. If a salesman comes around and wants to sell fire hose and does not get very enthusiastic greeting from the city manager he tries to go to the commission, as they generally do with a city council. The commissioners say, "We are very busy today. We have hired a city manager to take care of such things," and he has to come back to me. When I decide what I want to buy I advise them what contracts should be entered into. By taking a little time and going into it very thoroughly I have managed to buy things for about half the usual price—anywhere from ten per cent to seventy-five per cent of the usual price—and get better material without any trouble at all. I do not purchase anything myself excepting the larger things where technical knowledge is required. I have a purchasing agent to buy most things. Drugs have been somewhat high the last year. We have had many more patients at the hospital than we had the year before. Nevertheless, by buying all drugs properly we saved the health officer's salary on drugs, based on exactly the same appropriation. We are paying our health officer $3,600 a year. The old one I think got $500 or $600 for part time. They got just what they paid for. We have a thoroughly competent physician at the head of the department, a man who is familiar with public health work. I do not believe that there is a better health department in the state of Michigan.

George M. Ilg, ASSOC. W. S. E.: You said at the beginning of

your talk that you were liable to be discharged at any time that the commission saw fit. Is that true? Wouldn't they have to prefer charges and prove them?

Mr. Cummin: No.

Mr. Ilg: That is very unusual, isn't it?

Mr. Cummin: No. That is the way the general manager of a corporation holds his position. If he is not satisfactory to the board of directors he has to get out. I am in exactly the same position.

Mr. Ilg: Have they the same system at Dayton?

Mr. Cummin: Yes.

A Member: What are the predominating vocations of the commission, or are there any?

Mr. Cummin: There are three manufacturers and one coal and lumber dealer and a labor union man, who, by the way, is an exceptionally strong man, a very valuable member of the commission.

A Member: Were these men, as a rule, in politics before the city managership?

Mr. Cummin: None of them was ever in politics.

A Member: I might say, in connection with the larger cities, there has been considerable discussion recently since the proportional representation idea has been tried in Ashtabula. You probably know that Ashtabula is the first city in this country to try the proportional representation plan. A large number of names are placed on the ballot and the man who has the largest number is elected; the man who has the next largest number is elected, and so on. When Mr. Fitzgerald was here about a month ago the question was asked him what he would suggest for a city the size of Philadelphia or Washington. He thought if the city were divided into five or seven districts, with councilmen or commissioners appointed within those districts, that it would work out very well. That is substantiated by the gentleman who was present from Australia, where the proportionate plan worked out very well.

Mr. Cenfield: In Chicago we are called on to elect a great many different officers. We are called on to elect trustees of the sanitary district. We are called on to elect aldermen, mayor, judges, state officers, county officers, until the length of our ballot staggers us. From my own experience I think there are many advantages in electing by districts. I know if we had elected our council-at-large a year ago the council would have been of one complexion. However, by electing by wards we had a sort of cosmopolitan council which more nearly represented the people than if we had elected men just because they belonged to a certain party. We have Independents, Democrats, Republicans, Socialists, in the council, whereas, probably if they had been elected at large they would all have been Republicans. It is hard for the people to differentiate, especially where you have a large number of candidates to vote for. They do not know them personally. They do not know much about them. Some of us that are interested in government know more about them than the others, but most of the people have to take the report of

the Municipal Voters' League, or the report of one of the newspapers and go to the polls and mark the ballot as the paper or the Municipal Voters' League or somebody else recommends.

Mr. Cummin: Proportionate representation would get you out of that.

A Member: I think Mr. Cummin stated a while ago in Jackson they wiped out party lines. Didn't you, Mr. Cummin?

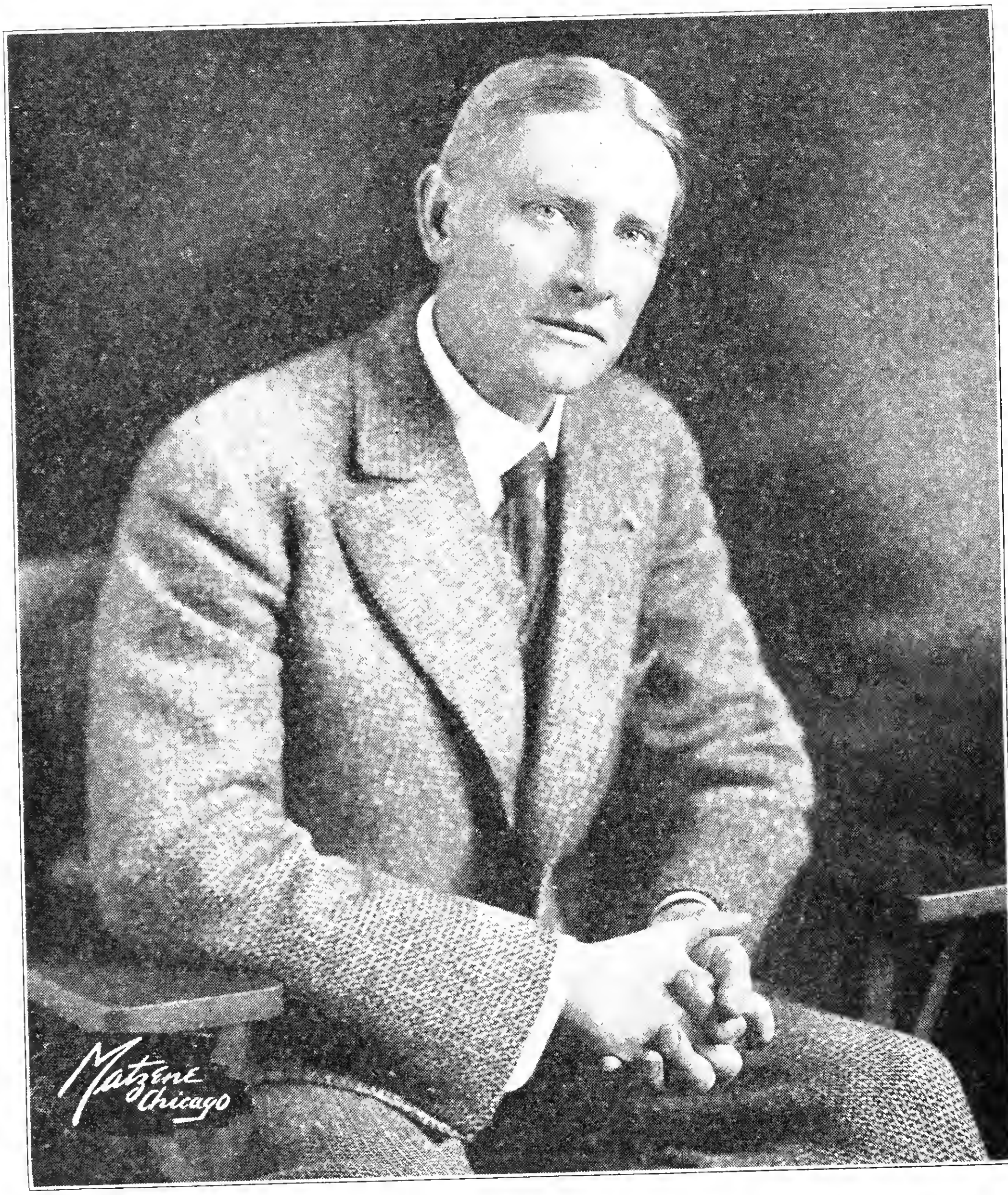
Mr. Cummin: Yes. It is a non-partisan election.

A Member: Isn't that partly due to the fact that you do not elect the whole house at a time?

Mr. Cummin: They are not elected under any party designation at all, you know.

A Member: Then also if you elected a city council in sections, say one-third each election day, you could not very well have a landslide by any one party. You would possibly have a landslide of one-third of them, but the other two-thirds might be of other politics.

IN MEMORIAM



CHARLES HOPKINS CARTLIDGE,
First Vice-President, Western Society of Engineers.

Died June 14, 1916

Charles Hopkins Cartlidge, First Vice-President of the Western Society of Engineers and a member since April, 1900, died at his home in Hinsdale, Illinois, June 14, 1916, after a brief illness of pneumonia. He was born April 29, 1869, in Hannibal, Missouri.

His career as an engineer should be an inspiration to other engineers and, therefore, it seems peculiarly fitting that a brief review of his life and professional work should be made a part of the records of this Society. He was graduated from the high school of St. Joseph, Missouri, in June, 1886. That same summer he was employed as a rodman on the preliminary survey for the Kansas City, Memphis & Birmingham Railroad. In the fall of the same year, he was a rodman for a level party on the preliminary and location surveys for the Kansas City and Omaha Railroad in Nebraska (now a part of the Burlington System) under Mr. R. L. Huntley, now chief engineer of the Union Pacific System. Regarding this early work, Mr. Huntley says:

"I recollect distinctly that, mostly through his efforts, the level party was always close to the transit party, regardless of the fact that they were running preliminary lines in a prairie country and often made five or six miles of preliminary survey in a day. Regardless of difficulties, Cartlidge was always good natured and pleasant and a very agreeable acquisition to a field party. He combined a pleasant disposition with the quality of being a hard, energetic worker, which is somewhat unusual."

During the following two years, young Cartlidge acted as material agent, receiving and forwarding rails, ties and construction materials, and as inspector of iron bridge erection for the Kansas City, Memphis and Birmingham Railroad.

In 1889, he served as Deputy County Surveyor in Buchanan County, Missouri, in charge of bridge and road work. This seems to have been his only experience in other than railroad engineering work.

In February, 1890, he entered the engineering department of the Chicago, Burlington & Quincy Railroad, as draftsman. He continued in that department until his death. In 1902, he was appointed Bridge Engineer for the entire system. While it was not his good fortune to be a student in or a graduate of a technical school, he was a great student during his entire engineering career and became one of the best informed of men in his particular field of engineering work. In addition to being well informed as to general practice, he was also a man of scientific spirit and original ideas, and was not afraid to deviate from established precedent when convinced in his own mind that something new and novel was better than what had been previous practice.

As bridge engineer, he was free to introduce new and original designs, and hence he became a pioneer in the use of reinforced concrete structures on his road.

Mr. Cartlidge contributed two important technical papers to this Society, as follows: "Design of Swing Bridges, from a Maintenance Standpoint—Read on April 18, 1906"; "Reinforced Concrete Trestles for Railroads—Read April 13, 1910."

The first of these papers treated of details of center and rim bearing and end-lifts of draw bridges. The paper brought out a very unusual amount of discussion, participated in by railroad engineers and bridge engineers in all parts of the country, so that the paper itself and the discussion form a most valuable record of prevailing and accepted practice at that time.

The second paper described the author's designs and actual construction of reinforced concrete railroad trestles, which at the time were unique, as little had been done in that direction by American railroads prior to the work done under Mr. Cartlidge's direction. An even more interesting contribution to the literature on reinforced concrete construction was the "Discussion" by Mr. Cartlidge in June, 1904, of a paper by Professor M. A. Howe in the *Journal* of this Society. In this discussion he described and illustrated one of a number of "flat top steel concrete culverts of large span with foundations proportioned to the different pressures along their lengths." The particular structure described was a double culvert, having a length of 207 feet and a width of 48 feet, there being two parallel openings of 17 feet clear spans and 24 feet depths from floor to roof. These flat top culverts built prior to 1904 are probably the earliest examples of strictly reinforced concrete railroad structures in the United States and they show the originality and boldness of Mr. Cartlidge in getting away from established practice into new construction of a character that has since become general among all railroads.

He was among the first, if not the first, in this country to design and use reinforced concrete decks on steel plate girder railroad bridges, and such decks were built from his designs as early as 1904. He also introduced reinforced concrete pipe culverts on the Burlington System in 1906, and built concrete pile trestles in 1908. Because of the reputation he established for himself as a reinforced concrete expert in railroad construction, he was selected as the Reporter for America by the International Railway Association, on "The Use of Ordinary Concrete and Reinforced Concrete on Railways," and compiled and submitted a report in 1914 for presentation at the International Railway Congress, which would have been held in Berlin in 1915 but for the European war.

About ten years ago, when the project of building a connection between the Burlington System and the railroads south of the Ohio River was under consideration, Mr. Cartlidge reported favorably upon the location of a new bridge across the Ohio River at Metropolis, Illinois. As the project grew, surveys, soundings and borings were made at this site and by 1914 construction work was definitely decided upon and Mr. Cartlidge was appointed Chief Engineer of the Paducah & Illinois Railroad Company, organized to build the twelve-mile connecting link between Metropolis, Illinois, and Paducah, Kentucky, thus connecting the Burlington System with the Nashville, Chattanooga & St. Louis Railway. He was placed in charge of both design and construction of the proposed bridge across the Ohio River at this point. The design of the structure embodied a number of novel and original ideas, including a new type of pneumatic caisson with roof supported by steel trusses. The largest of these caissons measured 66 feet by 110 feet at the cutting edge and the pier which it supports contains 16,000 cubic yards of concrete, being one of the largest piers in the United States. The design of the superstructure is notable as it included the longest simple truss span built for railroad traffic up to that time; this span, over the channel, being 720 feet center to center of end pins. Silicon steel was used for the compression members of all of the spans and nickel steel for all eye-bars and pins. The bridge required 18,000 tons of steel and was under construction at the time of Mr. Cartlidge's death. He gave to its construction a large measure of his time and energy. His inspection of the caisson work under air pressure of more than 50 pounds per square inch probably was one of the contributing causes of his fatal illness.

While the Metropolis Bridge was the crowning effort of his professional career, there were many other important bridges designed and built under his direction, including the Plattsmouth Bridge over the Missouri River, with 400-foot span, and the new double-track bridge at Kansas City, built during 1915-16 to replace the earlier structure built in 1866.

Mr. Cartlidge was a member of the American Railway Engineering Association and chairman of the Committee on Iron and Steel Structures of that Association during 1911-12. As chairman and member of this committee he took a very active part in the road tests made by that committee during several summers, on the impact effect of moving trains on track and structures. His enthusiastic interest in this work was undoubtedly one of the most influential factors in securing the funds to make it possible. He was also a member of the American Society of Civil Engineers, the American Society for Testing Materials and the Chicago Engineers' Club. He was Vice-President of the Chicago Engineers' Club from 1909 to 1912.

September, 1916

On December 25, 1893, Mr. Cartlidge was married at Oak Park, Illinois, to Miss Louie Estelle Almy, who, with a daughter, Catherine, survive him, as also his mother and four sisters. His family life was a beautiful one, for he was a most devoted son and brother and an affectionate husband and father. His splendid character won for him the esteem and confidence of his associates and gained him a host of friends and admirers, both in and out of the engineering profession.

Memoir prepared by W. L. Breckinridge, T. L. Condron and F. E. Turneaure, Committee.

NOTICE TO MEMBERS

In compliance with the requirement of the Constitution that vacancies in the offices of the Society shall be filled by the Board of Direction, the Board, at its meeting on September 14th, held an election to fill the vacancy caused by the death of First Vice-President Cartlidge, with the following result:

D. W. Roper, First Vice-President to fill the unexpired term of Mr. Cartlidge.

H. J. Burt, Second Vice-President to fiill the unexpired term of Mr. Roper.

September, 1916

ILLINOIS ENGINEERS DOING DUTY IN TEXAS

The Western Society of Engineers is represented in Company A, Illinois Engineers, now in Camp Cecil A. Lyon at Fort Sam Houston, San Antonio, Texas, by a number of officers and privates, as shown in the following list:

Horace S. Baker, First Lieutenant.
C. C. Saner, First Sergeant.
D. A. Tomlinson, Supply Sergeant.
James A. Cook, Corporal.
H. F. Beyer, Private.
M. D. Kolyn, Private.
Max Kushlan, Private.
N. M. Stineman, Private.

Several other members, who were originally with the company, were excused at Springfield for legitimate reasons.

Lieutenant John B. Swift, who is now in Chicago on recruiting duty, is very enthusiastic and strongly asserts that an exceptional opportunity is now offered to young engineers to obtain practical experience which will be invaluable to them in after life. He says that, not only the great engineering experience, but the physical training and camp life is well worth the time of any young engineer. The corps of engineers is the highest ranking branch of the service, and owing to the technical nature of the work, the chances for promotion are exceptionally good.

Company A was called out on June 18th, and on June 20th left for the mobilization camp at Springfield. Although not the first to entrain, they were the first to arrive at the mobilization camp. They remained there until the evening of July 4th, when, after being mustered into the service of the United States, they entrained, together with the Illinois Signal Corps, bound for San Antonio, Texas. On July 7th they arrived in San Antonio. Here they made their own camp. The first work given them was to design and build a complete drainage system for the entire camp. The designing and superintendence of this was done by the men of Company A and the labor performed by civilian laborers. Culverts were built at all road crossings.

The company was divided into four sections: the Reconnaissance Section, the Bridge Section, the Demolition Section, and the Fortification Section. The Reconnaissance Section, under Lieutenant Baker, made a complete survey of the entire camp, and Private Stineman made a detailed contour map of the camp, showing the location of all buildings, etc.

A Texas citizen donated the use of some land at New Braunfels, 30 miles from San Antonio, for a sub-camp. Lieutenant Guilfoil and ten men of the Demolition Section laid out a complete brigade camp.

The next important work was the making of a map from San Antonio to Austin, a distance of 85 miles, a complete map for one mile on each side of the road being made. This was done by the Reconnaissance Section, it being divided into four parties, one at camp, one at New Braunfels, one at San Marcos and one at Austin. The party was equipped with motor trucks, automobiles, motor cycles and horses. This map is now being used in the big division march which is being given so much publicity in the newspapers.

The company is well supplied with everything in the way of equipment, food, clothing, etc., and are making an enviable record for themselves, in fact, their record is so good that they will in all probability be the last troops to be mustered out of service on account of their valuable services to the Army. The company roster shows that over one-third of the men are technical graduates and that the personnel of the company is very far above the average of the ordinary engineering company in the United States Army. Nearly every man has had considerable engineering experience and is giving his best to the service. Ever since the company has been in camp, they have been going on a hike each morning before the regular work of the day begins. Starting with two miles, they are now doing about ten miles regularly every morning to limber themselves up for the day's work. Each afternoon, when not on special work, two hours instruction is given to each section. There have already been four men from the company authorized to take the examination for Second Lieutenant in the regular army. Company A is not attached to the Illinois troops, but is under direct orders of the division headquarters, and may be assigned to duty wherever the division commander may desire.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETING.

Meeting No. 942, September 11, 1916.

SMOKER.

The meeting was called to order at 8 p. m. by President Grant, with about 120 members and guests present.

After a few words of greeting from the President, Mr. A. S. Baldwin, M. W. S. E., Chief Engineer of the Illinois Central Railroad, was introduced, who gave a brief recital of some of the difficulties encountered and of the work done by the Illinois Central in times of flood in the lower Mississippi Valley. Mr. Baldwin then introduced Mr. John K. Melton, official photographer of the I. C. R. R., who described four reels of moving pictures which he had taken, depicting flood scenes, levee building and general conditions along the lower Mississippi River and its tributaries in time of flood.

During the intermission between the second and third reels, Mr. William H. McCaully surprised many of his brother engineers by telling some excellent dialect stories which fitted in very appropriately with the pictures, and also by some expert playing of the harmonica. Vocal and instrumental music and cigars occupied the other intermissions.

The meeting was adjourned shortly after 10 o'clock, refreshments and sociability being enjoyed for the next half hour.

E. N. LAYFIELD,

Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY.

How to Make a Transformer for Low Pressures. By Professor F. E. Austin. Published by the author, Hanover, N. H. 4½ inches by 7 inches. 17 pages. Second edition, cloth. Price, 40c.

The first edition of this little book was well received and a number of questions that were raised have been answered in the second edition. This second edition should prove very useful, particularly to those who wish to make and operate small transformers for experimental purposes.

Practical Surveying for Surveyors' Assistants, Vocational and High Schools. By Ernest McCullough. D. Van Nostrand Co., New York, 1915. 400 pages; 5 in. by 7¼ in. Price, $2.00 net.

The author had a wealth of experience in surveying work in his earlier days in various official positions, and also has had considerable experience as an editor, author and teacher. The first part of the preface states very clearly the purpose of the book, as follows:

"Modern texts on surveying assume the student to have completed the mathematical work in high school and college in algebra, plane and solid geometry, trigonometry and analytical geometry. This book is a serious attempt on the part of the author to meet the needs of students whose mathematical preparation does not extend beyond the arithmetic given in the grade schools. It is intended, therefore, to be a text book in high schools, vocational schools and evening classes. It is intended also as a text for self-tutored men in the employ of surveyors who wish to become surveyors."

The author's intention, as thus expressed, has been well carried out, and he has produced a book which will be useful to those to whom the mathematical portions of other books on surveying were unintelligible, while at the same time the practical points of the book, based on the author's wide experience, will be useful to those to whom mathematics would be no bar.

The author's style is clear and interesting, and he brings out in a very practical way the legal aspects of the surveyor's work, particularly in the distinction that he emphasizes between the "original survey and a re-survey." The author states in the introduction:

"In an original survey the corners are established. This can never again be done. If by any chance the marks are lost surveyors are employed to "re-locate" if possible the position of the corners, but no man can "re-establish" anything once established. A surveyor, making a re-survey, can only say that he has gone over the lines to the best of his ability from information given to him and believes he has set marks as nearly as possible where the original marks were placed."

One chapter of the book, devoted to "Surveying Law and Practice," contains Chief Justice Cooley's well known address on the Judicial Functions of Surveyors, as well as many references to court decisions relating to the work of the surveyor.

There is an excellent elementary chapter on Engineering Surveying, with references to more extended works on the various special divisions of the subject.

The contents of the book are as follows:

Chapter 1—Introductory.
Chapter 2—Chain Surveying.
Chapter 3—Leveling
Chapter 4—Compass Surveying.
Chapter 5—Trigonometry.
Chapter 6—Transit Surveying.
Chapter 7—Surveying Law and Practice.
Chapter 8—Engineering Surveying.
Appendix A—The Essentials of Algebra.

Theory and Practice of Modern Framed Structures. By Johnson, Bryan and Turneaure. Part III, Design. 9th edition, rewritten by F. E. Turneaure and W. S. Kinne. John Wiley & Sons, Inc., New York, 1916. 6 by 9 in.; 486 pages. Cloth. Price, $4.00.

This volume contains the "Practice" mentioned in the general title of the new edition of this handbook, and will be welcomed by all who have read or studied the first two volumes dealing with the theory of framed structures.

This volume will be of great value to the student or young engineer rather than to the older, experienced engineer, because it deals chiefly with the problem of proportioning structural members after the stresses are known. However, the discussion on Compression Members and Secondary Stresses, and other chapters, will also be very useful to the practicing structural engineer.

The first four chapters deal with the Styles of Structures, Working Stresses, Tension Members, Compression Members, Combined and Secondary Stresses. Chapter V contains a detailed discussion of Riveted Joints which is unusually complete and clear. Chapter VI is the best resumé of Plate Girder Bridge Design to be found anywhere. A little over 90 pages are devoted to this chapter, yet there is no problem that did not receive adequate treatment.

Chapters VII to XI, inclusive, contain the principles of the Design of Trusses, pin-connected and riveted, for deck and through railway and highway bridges, and roofs. Examples of designs are given, and detail plans of various types of structures appended.

The general specifications for steel bridges of the American Railway Engineering Association are given in Appendix A, and some standards are tabulated in Appendix B. Appendix C contains a discussion of unsymmetrical bending, a problem which is of some importance in the design of purlins, etc.

This volume completes the new edition of a standard work on structural design of the highest reputation, and is indispensable for the structural engineer's library. A. W. H.

LIVE LOAD STRESSES IN RAILWAY BRIDGES. By George E. Beggs, A. B., C. E. Published by John Wiley & Sons, Inc., New York. 6 by 9 in., 123 pages. Price, $2.00 net.

The author has made a conscientious attempt to assist the student and computer in analyzing live load stresses in railway bridges. The tables at the end of the book are probably better arranged than any others that have as yet appeared and are to be highly commended.

On account of these tables the book is easily entitled to a place in the practicing structural engineer's library.

Tables are given for Cooper's E 40, E 50 and E 60 loading. At first sight this seems an unnecessary duplication of work, as the stresses for any one loading may be transferred into that of either of the other loadings by a simple fixed proportion. In practice, where the various loadings are used, it is found quite economical to have the separate tables worked out so that there is really an economy for the reader in having the tables for the different loadings at hand.

The first part of the book, the explanation and development of the theory of influence lines, cannot be said to offer as much as the tables. The matter contained is not clearly given, nor is it developed in a properly consecutive and consistent manner. At times, the reader is supposed to have no intelligence whatsoever, while at other times the author assumes a thorough and complete knowledge of the subject on the part of the reader.

There is some good material given, especially in the matter of equivalent uniform loads, but it is a question if there is anything in the text of the book that is not better and more easily grasped by a study of Prof. Turneaure's exposition of the subject of influence lines in his "Theory of Framed Structures." I. F. S.

SCIENTIFIC MANAGEMENT AND LABOR. Robert Franklin Hoxie, Associate Professor of Political Economy, University of Chicago. D. Appleton & Co., New York and London, 1915. 300 pages, 5 inches by 7½ inches.

Professor Hoxie was employed by the United States Commission on Industrial Relations, of which Frank Walsh was chairman, to vestigate the scientific management systems of Frederick W. Taylor, H. L. Gantt, Harrington Emerson and their followers, in their relations to labor. Prof. Hoxie was assisted by Robert G. Valentine, designated as an industrial counselor, who was supposed to represent employers, and John P. Frey, editor of the "International Moulders' Journal," representing organized labor.

The author states in the opening chapter that at the hearings before the Commission on Industrial Relations "it developed that the representatives of organized labor stand in almost unqualified opposition to what they regard as scientific management and that the claims and counterclaims put forward by scientific management and labor leaders are far-reaching and apparently in irreconcilable conflict."

This fact is hardly surprising in view of the history of labor organizations in their efforts to limit output and destroy efficiency.

The author lays down the following principle—Scientific management,

in its relation to labor, must be judged, not merely by the theories and claims, either of its representatives or opponents, but mainly by what it proves to be in its actual operation. Mr. Taylor replies that if the principles that he lays down are violated scientific management ceases to exist. The author replies to this that the acceptance of this dictum would lead to endless quibbling and would prevent the drawing of significant conclusions as to the actual character and tendencies of scientific management and its effects upon labor welfare.

It will be seen, therefore, that the only way the author could make much progress was to set up his own problems as he went along and attempt to solve them. This he has done, with what seems to the reviewer to be a tender solicitude for organized labor rather than for the ultimate consumer.

The conclusions reached are, briefly, as follows: Scientific management, at its best, exemplifies one of the advanced stages of the industrial revolution which began with the invention and introduction of machinery. For the present, however, the introducers of scientific management have no influences to direct them, except where labor is thoroughly organized, other than their personal views or sordid desire for immediate profit with slight regard to labor's welfare. Neither organized or unorganized labor finds in scientific management any protection to its standards of living or any opportunity to create for itself a progressively efficient share in efficient management.

Notwithstanding the apparent bias of the author, the book is well worth reading, as it contains a large amount of data, which is presented in a readable form, and also a number of tabulated appendices showing the claims of the several scientific management systems, the trade unions' objections to them, etc.

Journal of the

Western Society of Engineers

Vol. XXI. OCTOBER, 1916 No. 8

LARGE MODERN LOCK GATES

By Malcolm Elliott.*

Presented March 13, 1916.

Only a hasty survey of modern practice in lock gate design is necessary to convince one that the design of lock gates is not standardized to the same degree as is the design of many other structures. The lack of uniformity in lock gate design is exemplified by the design, within recent years, for three locks of about the same dimensions, of three entirely different types of gates. The three

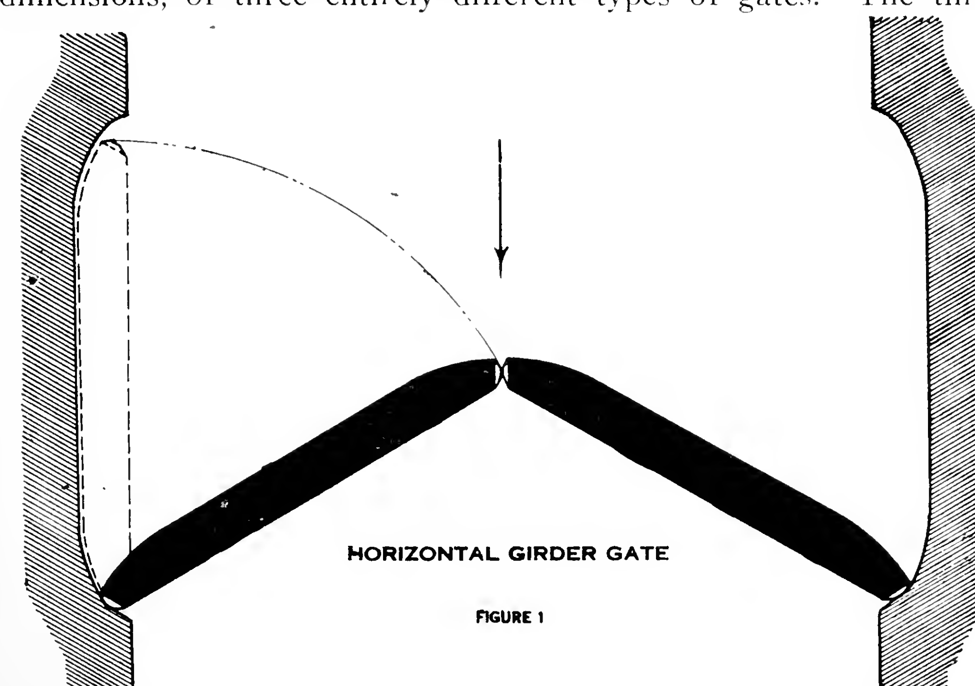


FIGURE 1

types referred to, fortunately for this discussion, represent the three types into which mitering lock gates can be classified. In this paper the three gates referred to will be described and compared in an effort to bring out some of the considerations that should control or influence the choice of type of lock gate.

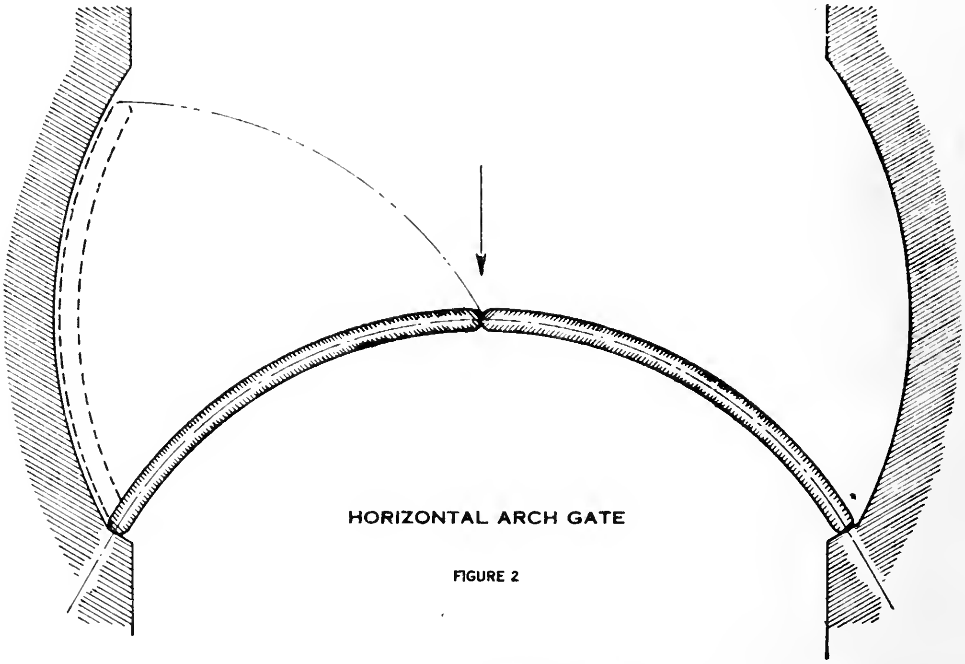
Broadly speaking, all mitering lock gates may be included in one or the other of *two* types, viz.: *vertically* framed and *hori-*

*U. S. Assistant Engineer, Louisville, Ky.

zontally framed. In the latter type the horizontal supporting members may be either circular arches or straight girders acting as beams. Including the two subdivisions of the horizontally framed type, it may be said that there are *three* types of mitering lock gates; these will be designated briefly as vertically framed gates, horizontal arch gates and horizontal beam gates.

A vertically framed gate resists the water pressure by means of a series of *vertical* girders more or less uniformly distributed throughout the length of the gate, and each vertical girder is supported at the bottom by a sill anchored into the floor of the lock and at the top by a horizontal member which is in turn supported at one end by the lock wall and at the other end by the corresponding member of the opposing leaf.

A horizontally framed gate is one which resists the water



HORIZONTAL ARCH GATE

FIGURE 2

pressure by means of a series of *horizontal* frames more or less uniformly distributed from the bottom of the gate to the top. Each horizontal member receives the load on its own portion of the gate and, like the upper member of a vertically framed gate, is supported at one end by the lock wall and at the other end by the corresponding member of the opposing gate leaf. The horizontal members may be either arches or beams.

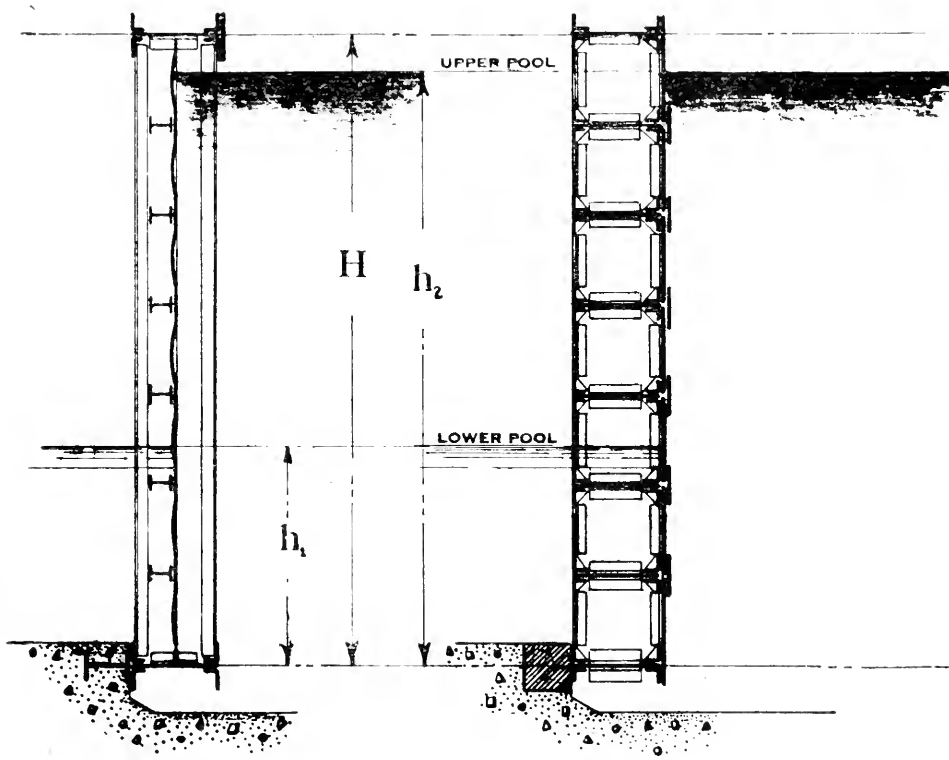
Fig. 1 shows a gate in its mitered position and may represent either the top girder of a vertically framed gate or any girder of a beam gate. Fig. 2 shows a gate in which the horizontal members are arches.

Fig. 3 shows the cross sections of horizontally and vertically framed gates and illustrates the distinction between the two types of framing.

The three lock gates described and compared in this paper will be referred to as the *Louisville, Panama and Keokuk gates respectively. All of these gates are for locks 110 feet wide (usable width) and are about 48 feet high. All of them are designed for water to the top of the gate on the pressure side and no water on the downstream side.

The Louisville gate is vertically framed, the Panama gate belongs to the beam type and the Keokuk gate belongs to the arched type.

With practically the same dimensions and identical conditions as to water pressure, there exists an unusual opportunity for com-



CROSS SECTION OF A VERTICALLY FRAMED GATE

CROSS SECTION OF A HORIZONTALLY FRAMED GATE

FIGURE 3

paring the three types. The fact that three designers, confronted with almost identical problems, arrived at three distinct solutions makes it proper to compare the various types, and as a result of this comparison it may be possible to reach some conclusion as to the best type of gate.

*These designations are adopted for convenience. The "Louisville" gate referred to exists on paper only, the design not having been approved. The real Louisville gate when built will be practically a copy of the Keokuk gate. The "Panama" gate referred to is the smallest of the 92 leaves built for the Panama locks.

LOUISVILLE VERTICALLY FRAMED GATE.

The gate shown in Fig. 4 was designed by the writer in 1913 and proposed for the new lock at the lower end of the Louisville and Portland Canal, Louisville, Ky. The design was rejected because the advantages claimed for it did not seem sufficient to warrant a departure from horizontal framing which seemed to be standard for gates of this size, and also because there was some doubt as to whether the limestone on which the lock was built was sufficiently sound to resist the large loads which a gate of this type would produce against the sill. The general dimensions of this gate are as follows:

Height, top of sill to top of water-tight skin, 48 ft. 0 in.

Length, center to center reaction castings, 59.69 ft.

Ratio of height to length, 0.80.

Weight of gate per leaf, 500,000 lbs.

It was designed for the water surface on the upstream side at the top of the gate and tail water excluded.

The main framing consists of quoin and miter girders and three intermediate vertical girders framed into horizontal girders at top and bottom. The bottom horizontal girder does not carry any computed portion of the horizontal water pressure on the gate, but acts as the bottom chord of a cantilever truss in the support of the dead weight of the gate.

The vertical girders are designed to carry the entire load on the gate. The upper ends are framed into and supported by the upper horizontal member and the lower ends of the verticals bear against the sill which is anchored into a concrete foundation keyed into a trench in the rock floor. The three intermediate verticals, it will be seen, are of the box type, so designed for a special reason which will be explained later. The vertical girders terminate at the bottom in brackets which bear against the sill. The object of this arrangement was to reduce the upward pressure on the bottom chord. If the gate should rest against the sill at the downstream edge of the bottom chord, the upward pressure would exceed the weight of the gate.

Of course the essential part of a gate is the water-tight skin or sheathing. The function of the framing is merely to support this sheathing and hold it in place while it is performing its duty. In this gate the sheathing is in the middle of the gate and was so located in order to make the gate symmetrical, thus reducing the tendency to warp. This symmetry of construction is not obtainable in large horizontally framed gates of either the beam or arch type. A large economy in weight would have resulted in this case from the use of buckled plates instead of flat plates for the sheathing, but at the time the design was made it was not known to the designer whether buckled plates more than ⅜ inch thick could be readily obtained and therefore flat plates were specified. The sheathing

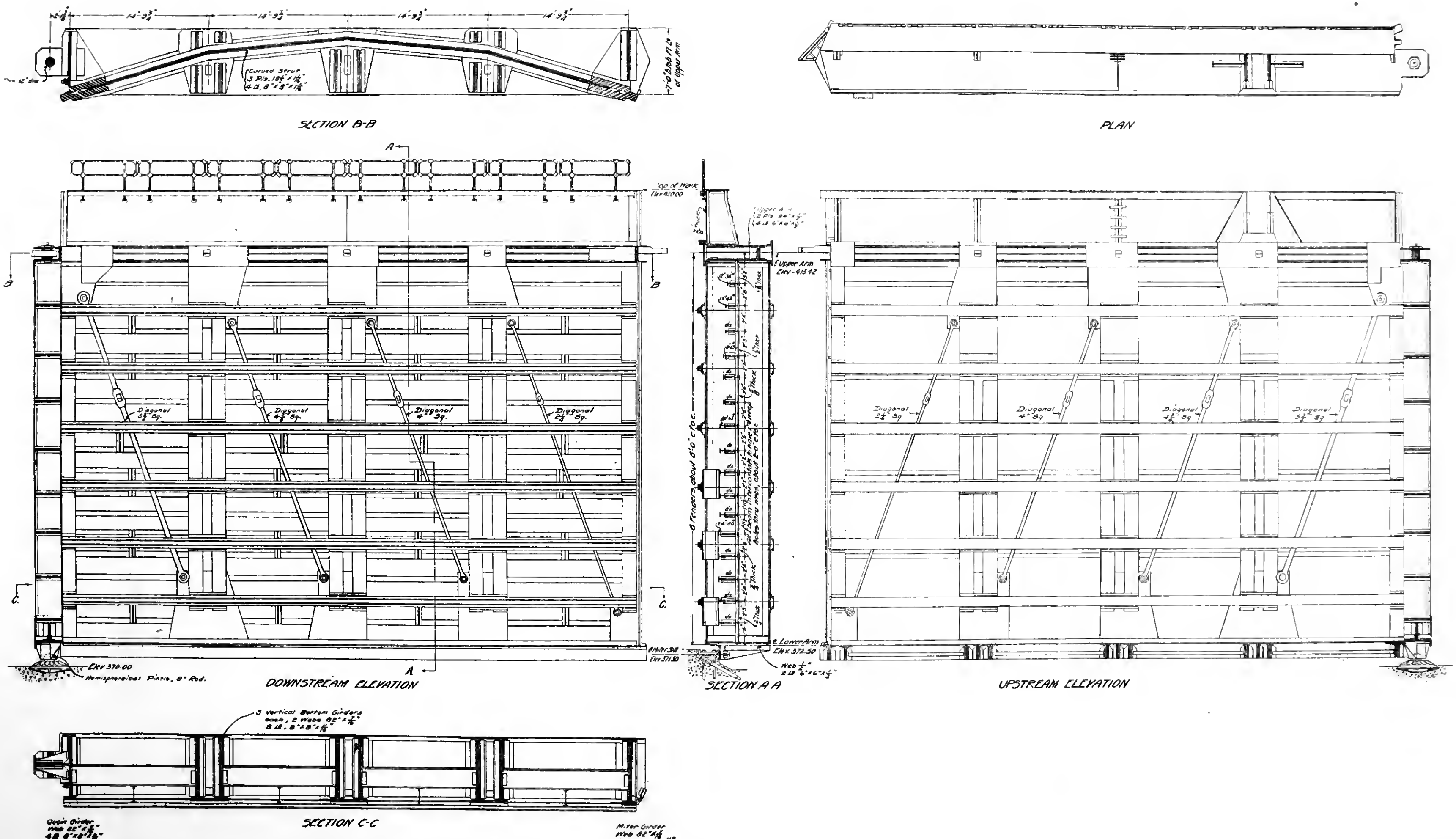

SECTION B-B
PLAN
DOWNSTREAM ELEVATION
SECTION A-A
UPSTREAM ELEVATION
SECTION C-C

Fig. 4

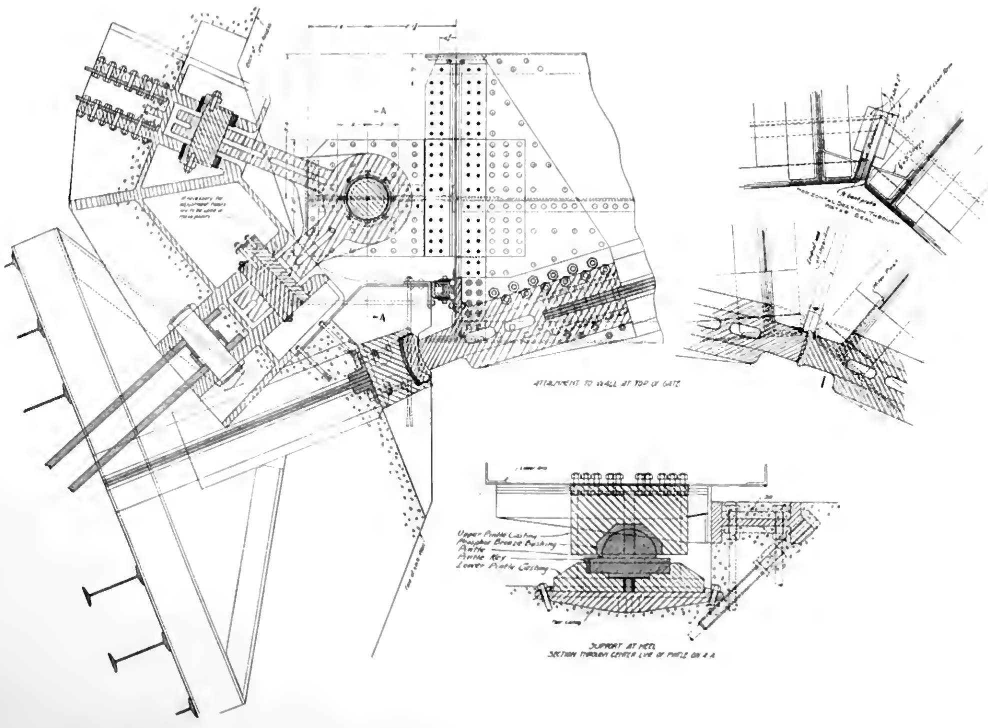

ATTACHMENT TO WALL AT TOP OF GATE
Upper Pintle Casting
Phosphor Bronze Bushing
Pintle
Pintle Key
Lower Pintle Casting
SUPPORT AT HEEL
SECTION THROUGH CENTER LINE OF PINTLE ON A A

Fig. 5

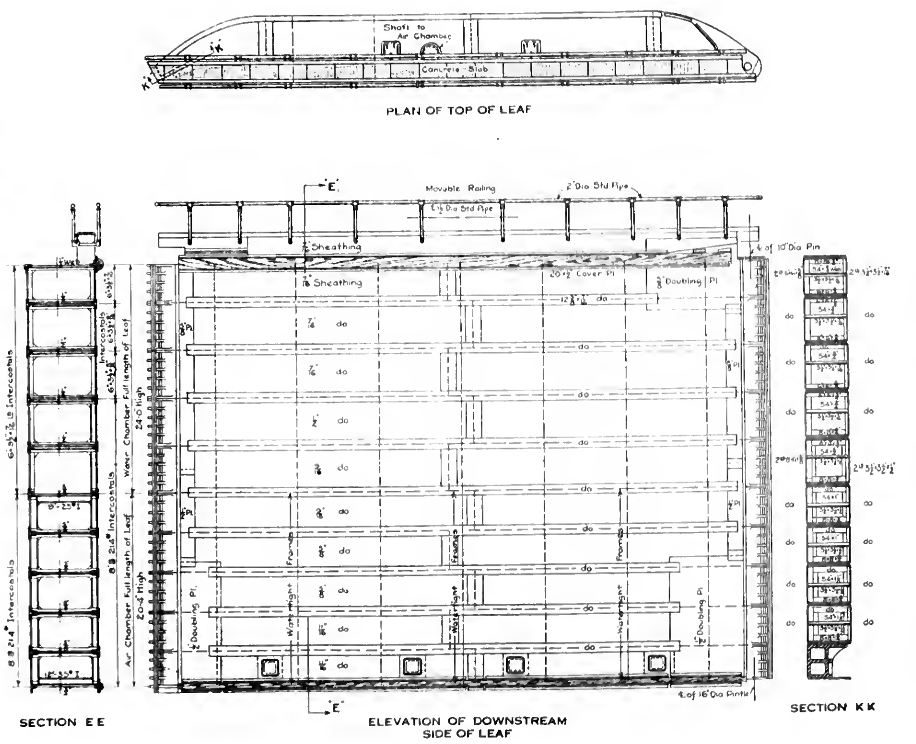

Shaft to Air Chamber
Concrete Slab
PLAN OF TOP OF LEAF
Movable Railing
2" Dia Std Pipe
1½ Dia Std Pipe
Sheathing
Cover Pl
Doubling Pl
Intercostals
Water Chamber Full length of Leaf
24'-0 High
Air Chamber Full length of Leaf
Framing
Watertight
of 10" Dia Pin
of 16" Dia Pintle
SECTION E E
ELEVATION OF DOWNSTREAM SIDE OF LEAF
SECTION K K

Fig. 6

plates are supported locally by I-beams framed into the vertical girders.

The horizontal girder which supports the upper ends of the vertical girders is supported at one end by the corresponding member of the opposing gate leaf and at the other end by a reaction casting in the wall.

The design of this upper horizontal girder is somewhat unusual, although it has been used on one other lock gate. In outline it resembles a box girder, but in reality it is an arch and the plates and angles composing the box girder merely serve as stiffeners for the arch and a means of connecting the latter to the vertical girders below. The arch consists of a strut of I-section enclosed within the plates of the box girder and is bent so that its axis coincides approximately with the thrust line of the arch. The bent strut, in order to coincide with the line of thrust, changes direction at the center line of each vertical girder. It was in order to keep the number of changes in direction as small as possible that the intermediate vertical girders were grouped in pairs making box girders instead of being distributed at uniform intervals throughout the length of the gate. With the bent strut as the top horizontal member there is a little saving in weight over the common plate girder construction, notwithstanding the apparently superfluous metal in the box girders enclosing the strut. The greatest advantage of this form of construction is in simplifying the end connections where the arch thrust is transmitted into the walls. The ends of the arch are provided with simple forked castings which bear against the wall castings when the gate is closed. (Fig. 5). With an ordinary plate girder, in this case, it would have been difficult to provide for the transmission of the end thrust into the girder flanges because the thrust is unusually great and the distributing member extending to the upper flange on the lower side of the plate girder would necessarily pass through an opening in the sheathing, the sheathing occupying a position almost midway between the point of contact and upper flange of the girder. With the bent strut or arch, the end connection, good for the strength of the arch, is easily made and there is no interference with the sheathing. The first time this form of construction was used, so far as the writer knows, was in the vertically framed gate* built within recent years at St. Paul, Lock No. 1, Mississippi River.

One of the distinguishing features of a vertically framed gate is the fact that the upper horizontal member is the only member that transmits thrust into the wall, and the contact between the gate and the wall and between the two leaves of the gate below the upper horizontal member is merely for the purpose of stopping the flow of water. With horizontally framed gates, on the other hand, each individual horizontal member acts as an arch in supporting the load and a thrust exists at the end of each horizontal member throughout

*Described in "Engineering News," July 2, 1914, p. 1.

the height of the gate. With large gates this condition necessitates an accurately located and finished reaction shoe in the wall, equal in length to the height of the gate and, a corresponding piece on the gate, located and finished with equal precision. With vertically framed gates, however, the thrust being concentrated at one point, the reaction shoe is a small affair and its adjustment very simple in comparison with that required for a horizontally framed gate. To provide contact between the wall and the gate and between the two gate leaves, below the upper horizontal member, a flexible medium is required so that the contact shall be sufficiently tight to exclude the water and at the same time not cause a dangerous amount of thrust. In many cases simple wooden blocks would be satisfactory. With the gate referred to, in order to avoid dangerous thrust, a more flexible arrangement was desired and accordingly the miter seal is a rubber cushion and the quoin seal is a casting held against the wall by spiral springs. Both of these are shown in Fig. 5. It is believed that a rubber cushion would be perfectly satisfactory for the quoin contact in place of the spring buffer.

This gate, like nearly all modern lock gates of the mitering type, is fastened to the wall at the quoin end without any rollers or other support under the mitre end. The design of these fastenings requires especial care because on their reliability the usefulness of the gate is absolutely dependent. The arrangement adopted is shown in Fig. 5. A 12-in. diameter pin keyed into pin plates at the top of the gate rotates in a bushing in a cast steel yoke which is anchored to the wall by means of an anchor box casting secured by two anchor arms extending into the concrete. Adjustment by means of wedges connecting the yoke to the anchor box is provided in order that the yoke may be accurately centered over the pintle.

At the bottom, the gate rests on a hemispherical pintle on which it also rotates; the pintle rests in a casting set in the floor. A socket fitting the pintle and lined with a bronze bushing is fixed to the gate. The pintle not only supports the weight of the gate, but also resists a horizontal force due to the lack of support at the miter end of the gate.

As to its support, the gate is essentially a cantilever truss, although it might also be considered a cantilever plate girder if the central sheathing is considered to correspond to the web. It was decided, however, not to rely on the sheathing to prevent sag because its resistance to sag would not be developed until enough sag had occurred to produce a deflection proportional to the resisting stresses and it was desired that this gate should be entirely free from any deflection whatever in order to promote efficiency in operation. With the adjustable diagonal tension members it was assumed that the sag in the gate could be taken up and that then the sheathing would be inert so far as supporting the weight of the gate is concerned. The diagonals also tend to prevent distortion of the gate leaf as it is moved through the water.

PANAMA HORIZONTAL BEAM GATES, 47 FT. 4 IN. HIGH.

Generally speaking, the larger gates, 77 ft. and 82 ft. high, of the Panama Canal would be more interesting examples of lock gates than the smaller gates chosen for this paper and shown in Fig. 6.* The smaller gates were selected as being comparable in size with other gates referred to in this paper and because of the similarity in size they afford a better opportunity of judging the relative merits of the principal types than would be the case if the larger gates had been selected for comparison.

The general dimensions of the Panama gates referred to in this paper are as follows:

Height, top of sill to top of water-tight skin, 46 ft. 10 in.

Length, center to center of reaction castings, 64.91 ft.

Ratio of height to length, 0.72.

Weight of gate per leaf, 750,000 lbs.

This gate is radically different from the Louisville gate just described. Instead of a series of vertical girders supported at the top and bottom by the upper horizontal member and the sill respectively, there are a series of eleven horizontal girders, each one supporting the pressure on a panel from four to five feet wide and transmitting these pressures into the lock wall. This is the fundamental distinction between vertical and horizontal framing.

The eleven horizontal girders are tied together and made to act as a structural unit by quoin and miter posts, seven intermediate vertical diaphragms, and the skin or sheathing on both sides of the frame. The seven intermediate vertical diaphragms perform no duty whatever in regard to the support of the water pressure but merely act as spacers for the horizontal members.

The gate is provided with a skin or sheathing on both sides. This arrangement adds greatly to the stiffness of the structure and permits dividing the interior of the gate into water and air compartments.

The water compartments have openings on the up-stream side and are of sufficient volume so that the water contained therein, together with the weight of metal in the gate, will exceed the upward pressure on the bottom of the gate when closed. The air chambers provide a certain amount of buoyancy, thus reducing the weight of the gate in water, reducing wear on the fastenings and making the gate easier to operate.

The double sheathing adds largely to the weight of metal in the gate and therefore to its cost. Its use is probably unavoidable in a gate of this size and type.

It will be seen that the girders are tapered near the ends and that the tapering occurs entirely on the up-stream side, the down-stream side remaining straight throughout. By reducing the depth

*The Panama lock gates are described by Mr. Henry Goldmark, M. W. S. E., in a paper presented to the International Engineering Congress, San Francisco, 1915.

of the girders near the ends, where the bending moment is small, a saving in weight is effected without loss in strength, but there is also, on this account, increased difficulty in construction.

This gate is hinged at the quoin end in a manner very similar to that described for the Louisville gate. There are no diagonal straps to prevent sag, the double sheathing providing all the stiffness necessary. There is no way to correct any warp or sag that might occur in the gate when it is swung on its hinges. The gates were built with such precision and are so stiff that no such adjustment was necessary.

The end thrust which exists throughout the height of the gate is received through jaw castings provided with adjustable bearing

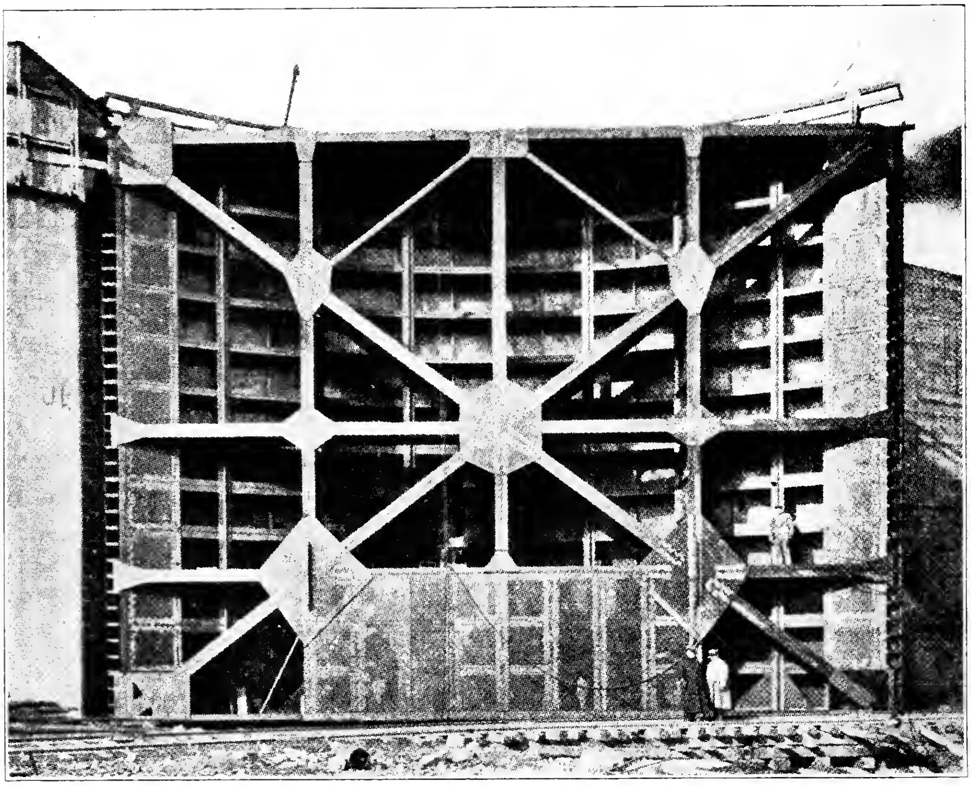


Fig. 7

strips (Fig. 6) which were forced into close contact after the gate was erected. The space behind the adjustable strip was then filled up with molten babbitt metal.

KEOKUK HORIZONTAL ARCH GATE.

This set of gates has been described fully elsewhere,* but a brief description is included here in order to make this discussion complete. The gate was built for the new lock at Keokuk and has

*Engineering Record, Sept. 18, 1915.
Engineering News, Nov. 13, 1913.
Engineering Record, July 26, 1913.

been in use since. It was designed under the direction of Mr. Hugh L. Cooper by Mr. B. H. Parsons.

The general dimensions are as follows:

Height, top of sill to top of water-tight skin, 48 ft. 0 in.

Length, center to center of reaction castings, 66 ft. 4¾ in.

Ratio of height to length, 0.72.

Weight of gate per leaf, 500,000 lbs.

It was designed for water on the up-stream side to the top of the gate and tail water excluded. The conditions and dimensions are generally the same as for the Louisville and Panama gates.

The system of framing is shown in Figs. 7 and 8.* Like the Panama gates, it is horizontally framed, but the supporting members are arches instead of straight girders. The axis of the arched frame is circular and the sheathing surface is cylindrical and of approximately the same radius as the arches; therefore, the stresses in the arches (the loads being normal to the cylindrical surface) are similar to the stresses in the shell of a stand-pipe except that they are opposite in direction. By this system of framing, the stress in any arch is constant throughout its length and evenly distributed over its cross-section.

The main framing of the Keokuk gate consists of thirteen arched ribs, uniformly spaced, 4 ft. 0 in. center to center. Each arch is of "I" section built up of plates and angles. The water-tight skin is riveted to the convex side of the skeleton and there is no skin on the down-stream side.

Designers of lock gates generally agree that the arched system of framing gives a lighter gate than the straight horizontal girders, but the former type has generally been considered as lacking in stiffness. The designer of the Keokuk gate was very successful in overcoming this defect which was supposed to be inherent in the arched type. This gate is provided with a system of rigid plate girders connecting the diagonally opposite corners of the gate on the concave side of the arch. These diagonal girders intersect and are riveted to each other at the center of the gate and are riveted to the arch ribs at the central point and at each end. They not only tend to prevent deflection at the miter end of the gate but also tend to prevent warping when the gate is moved against the resistance of the water at the bottom of the leaf by the operating force applied at the top.

The lack of stiffness in arched gates is due generally to the fact that the arched ribs are of less depth than straight girder ribs. Furthermore the warping effect is greater because the center of gravity of the gate, owing to its curved shape, is further away from the center of support giving the gate a larger torsional or twisting moment, than is the case with beam gates. The effect of this eccentricity and lack of stiffness is to twist the gate leaf so that the miter post is out of plumb; the upper end being up-stream and the lower end down-stream from the true position. With the arched

*Reprinted by permission from Engineering Record, Sept. 18, 1915.

lock gate in the Poe lock at Sault Ste. Marie, computations in advance of the construction indicated that the miter post would be out of plumb ⅝ in. The writer has no knowledge as to whether or not this condition was realized after construction. With the arched gates at the Cascades Canal in Oregon, the miter posts were found to be out of plumb as much as $1\frac{3}{16}$ in. On account of the effective system of diagonal bracing adopted at Keokuk, no such deflection existed and the success of this system demonstrates that the lack

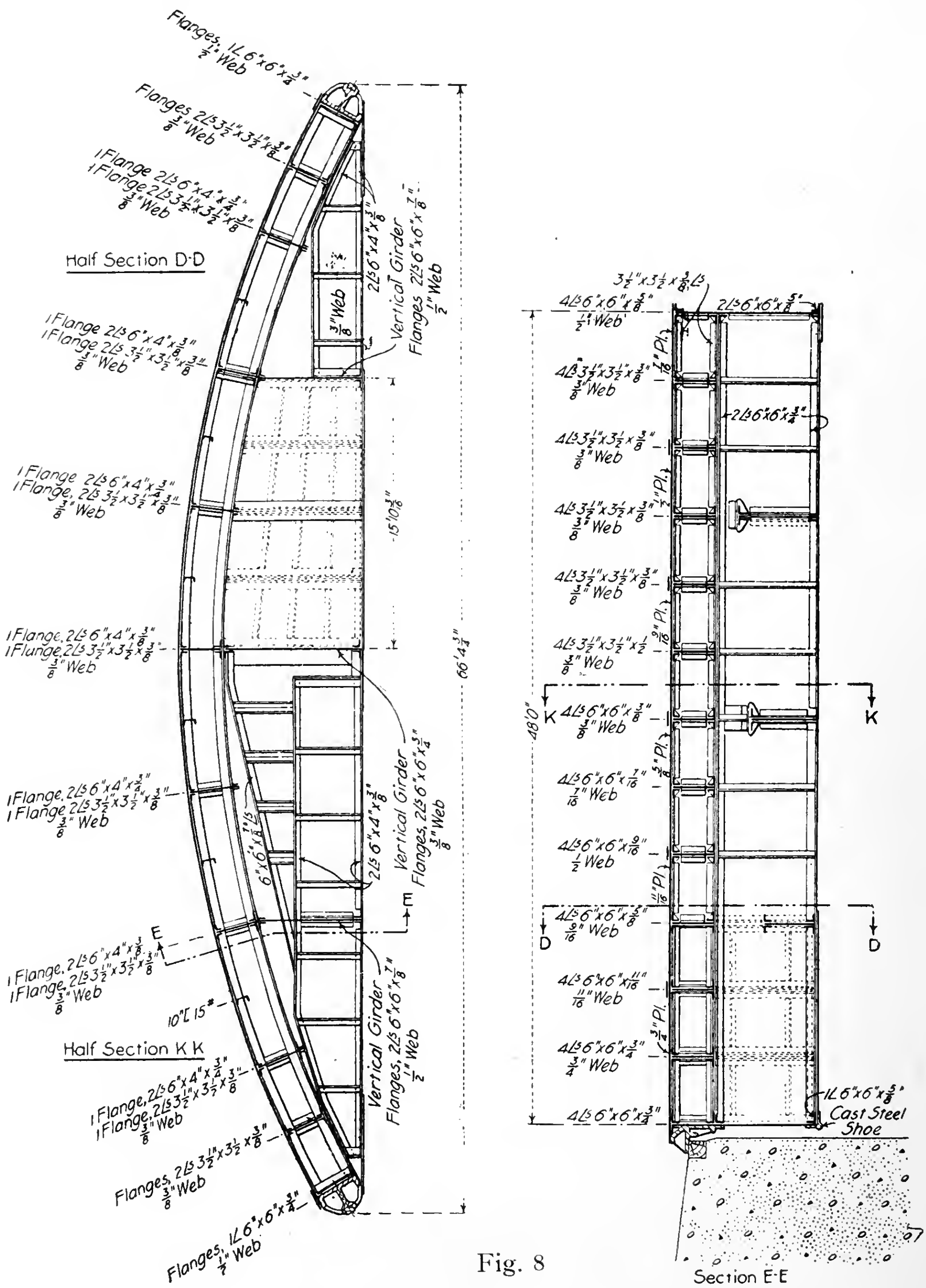


Fig. 8

of stiffness, supposed to be inherent in the arched gate, may be readily overcome.

In order to reduce the loads on the fastenings of the Keokuk gate, an air tank or buoyancy chamber is provided on the downstream side of the gate near the bottom. The sill contact is near the up-stream side of the gate and hence there is little or no upward pressure when the gate is closed.

This gate had recently been completed at the time the Louisville design described herein was rejected. Its economy was so marked as compared with the beam type and its operation was so satisfactory that the Keokuk type was adopted for Louisville and the ap-

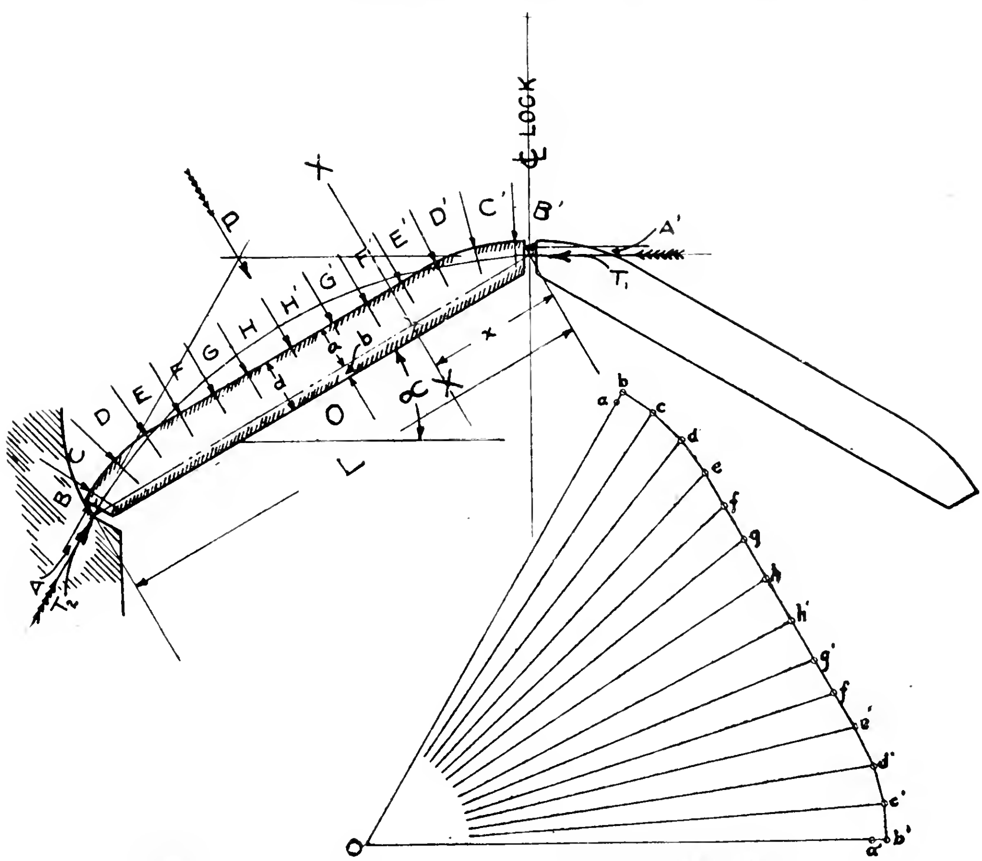


FIGURE 9

proved design is practically a copy thereof, the only changes being a slightly different spacing of the horizontal arches and the elimination of the buoyancy chamber. On account of the large amount of sediment in the river at Louisville during high water, a buoyancy chamber would require frequent cleaning out, causing a maintenance expense which it was believed would be out of proportion to the benefits derived from a buoyancy chamber.

This brief description of three gates of similar dimensions and for almost identical conditions, but of radically different types, is intended to serve as a basis for a discussion of the three types in

an effort to bring out the advantages of each and arrive at some conclusion as to their relative merits.

First it will be necessary to review briefly the manner in which a lock gate resists the forces acting on it and analyze the effects of these forces on the members of the gate.

Fig. 9 shows a beam gate in its mitered or closed position. Since the two leaves are in every way symmetrical about the center line of the lock and the contact surface between the leaves coincides with the center line of the lock, the end reaction, T, must be perpendicular to the center line of the lock. If this force is produced to intersect the resultant, P, of the unit loads AB, BC, etc., and through this intersection a line is drawn through the point of contact at the quoin end this line will give the direction of the reaction, T_2, at the quoin end. It is clear, from Fig. 9, that the end reactions are equal to each other and make equal angles with the axis of the gate and that the angle in each case is equal to α, or the complement of one-half the miter angle.

It is shown in Appendix A that the stresses in the upper and lower flanges are, respectively,

$$F_1 = \frac{p}{d}\left(\frac{Lx}{2} - \frac{x^2}{2} + \frac{Lb \cot \alpha}{2} + ab + \frac{a^2}{2}\right), \text{ and}$$

$$F_2 = \frac{p}{d}\left(\frac{Lx}{2} - \frac{x^2}{2} - \frac{La \cot \alpha}{2} - \frac{a^2}{2}\right).$$

When x is small the expression for F_2 becomes negative indicating compression near the ends. Neglecting the terms ab and $\frac{a^2}{2}$, which are small compared with the other terms, it is apparent at once that the stress in the up-stream flange decreases as b is decreased. As b is decreased, a is increased; therefore, the stresses in the down-stream flange are decreased as b is decreased so long as the positive term exceeds the sum of the negative terms. When the expression for F_2 becomes negative, an increase in a (or decrease in b) increases the stress in the down-stream flange by an amount equal to the decrease in the up-stream flange, the sum of the two stresses remaining the same. Hence, by moving the point of contact down-stream, there is a saving in weight near the middle where the up-stream flange is in compression and the downstream flange is in tension. Near the ends where both flanges are in compression, there is neither a saving nor a loss. Considering the girder as a whole, the point of contact should be as far down-stream as possible for economy in weight.

The stresses in a circular arch gate are easily analyzed. The compression in the arch ribs, if the point of contact is on the axis of the arch, is constant throughout the length of the arch and evenly

distributed over its cross-section. The arch thrust will be equal to pr where p = the load per unit of length and r = the radius of curvature.

The above is a brief analysis of the effects of *known* loads on the horizontal members of a lock gate. The determination of the *loads* on a horizontally framed gate is another and more difficult matter.

If all the horizontal members were connected only by a flexible water-tight sheet, each would carry a load exactly proportional to the head acting on it. But lock gates cannot be so constructed. The various members must be tied together so that the whole structure can be manipulated as a unit. When the gate is closed and the water pressure is applied, the bottom of the gate may or may not be in contact with the sill. If there is no contact with the sill, the load on each girder will be approximately that due to its depth below the surface and the panel width which it supports. If the gate rests against the sill and is restrained from being deflected down-stream in proportion to the load it bears, the lower girders will be relieved of a part of their loads and this amount will be transferred into either the sill or the upper girders or both. The ordinary practice is to design the lower girders for loads due to depth and assign to the upper girders loads greater than those due to the depth, these extra loads being caused by vertical stiffness. At the same time, if the gate does *not* bear against the sill the vertical stiffness will have little effect in modifying the loads due to depth and the lower girders will then not be relieved of any part of their loads.

A method of computing this excess load due to vertical stiffness is given in Gen. Hodges' *"Notes on Mitering Lock Gates." This method is easily applied and doubtless gives satisfactory results although it is not strictly correct in theory. No better method of analysis has yet been proposed, so far as the writer knows.

Due to the fact that the lower girders may be subjected to the full hydrostatic loads, without reduction on account of vertical stiffness, and that the upper girders are designed for loads greater than the hydrostatic loads, the total assumed load on the gate, by General Hodges' method, is greater than the actual water pressure. If the water is even with the top girder on the up-stream side and excluded from the down-stream side, the assumed load, according to General Hodges' equations, is one and one-ninth times the total actual water pressure.

With a vertically framed gate there is no uncertainty as to the loads on the main members nor as to the stresses produced by these loads. The top horizontal girder supports its loads in the same manner as the horizontal members of a horizontally framed gate and

*"Notes on Mitering Lock Gates," by First Lieut. Harry F. Hodges, Corps of Engineers, U. S. A., Professional Papers No. 26, Corps of Engineers, Washington; Government Printing Office, 1892.

there is no uncertainty as to the amount of the load. Referring to Fig. 3, and taking moments about the sill, the unit load p, on the top girder, is found to be $\frac{62.5}{H}\left(\frac{h^3_2}{6} - \frac{h^3_1}{6}\right)$. When h_1 = zero and $h_2 = H$, the load p becomes $62.5 \frac{H^2}{6}$, which is one-third of the total water pressure. The other two-thirds are carried by the sill. The vertical girders are readily determined analytically or by diagrams in the usual manner.

The foregoing is a brief outline of the most important principles of lock gate design. The next point to be discussed is how these principles affect the design of lock gates, with especial reference to the relative costs of the three types.

√ Comparing horizontal rectilinear girders with horizontal arches as applied to lock gates, it will be seen that, as to weight, there is an advantage in favor of the arched type. This is on account of the method of support of the applied loads. With girders there is a combined direct thrust and bending and with circular arches there is a direct thrust with no bending. NP

That arched framing will be lighter than beam framing is proved analytically in *Appendix B* where it is shown that the volume of an arched frame will be $0.345 \frac{pB^2}{f}$, and the volume of the flanges alone of a beam gate will be $0.348 \frac{pB^2}{f}$, where p = the unit load on the gate and B = the width of the lock between hollow quoins and f = the unit stress. When the webs are added to the expression of the volume of a beam gate the difference in favor of arched framing will, of course, be greater. The difference will, in fact, be more marked than as indicated by this analytical treatment because the flanges of the beam type were assumed to be "perfect"; that is, to vary in area throughout in proportion to the ever-changing flange stresses. This condition, of course, cannot be realized in practice and the actual flange will be greater in volume than theoretically required. With an arched gate, on the other hand, the stresses are constant throughout the length of the gate and there is no difficulty in making the actual area agree almost exactly with the theoretical area.

Notwithstanding the advantage in weight in favor of the arched gates, this type is not universally favored by writers on lock gate design. It is claimed by some that the arched form of gate lacks the stiffness and the ability of the beam type to withstand shocks. With the exception of the Keokuk gate, the writer is of the opinion that, as far as it refers to lack of stiffness, this criticism has been more or less justified with large arched gates that have been built

to date. The lack of stiffness has not been so serious as to interfere greatly with the proper working of the gates referred to, but it is certainly to be avoided if possible, and for that reason the efficient bracing adopted for the Keokuk gate is a distinct step in advance and the demonstration of the effectiveness of this system should go a long way toward removing the objections of designers to the arched type of gate..

As to the ability to withstand shocks, it may be said that, other things being equal, the heaviest gate will be superior, but the chances of accident and the value of heavier gates are not sufficiently great, in the writer's opinion, to justify the adoption of uneconomical framing merely for the purpose of providing against accident.* It would be better to adopt the most economical framing and then add the metal saved by economical design in the place where it would do the most good in minimizing the chances of damage from accidents.†

Another objection stated against arched gates is that a large amount of curved work is required and the effect of this is to increase the price per pound, thereby largely, if not entirely, offsetting the economy due to less weight. This objection is probably justified in the case of small gates where the choice is between straight rolled I-beams and curved built-up plate and angle arches. With larger gates, however, even when straight girders are used there is a large amount of curved work due to the practice of tapering the girders, for the sake of economy, near the ends where the bending moment is small. It is not believed that such girder gates are any cheaper per pound than arch gates.

There is a very serious objection to arch gates where there are locks in pairs, side by side, as in the Panama Canal. An arched gate

*The large list of accidents to the beam gates of the Welland Canal indicates how little value the use of horizontal girders has in preventing accidents.

†A unique statement of the effects of a blow from the downstream side of a gate is contained in the following words of an authority on the design of river improvements:

> "The comparative ability of the arched and the straight girder type to withstand shocks may be illustrated by supposing a boat to strike, with sufficient impact to force the leaf open, the lower side of a girder supporting a head of water. In an arched girder, which depends for its equilibrium under a load on a fixed direction of the resultant pressures at the toe, the framing is suddenly submitted to intermediate bending stresses for which it was not designed, and which, if the pressures are great, may distort it seriously. In a straight girder, which acts as a beam, the point of support is merely changed from the toe to a point a few feet distant (as the point of impact when a boat strikes a gate is almost invariably near the miter), and the supporting power of the girder remains practically unimpaired."

The author of the above does not state what would occur in the meantime to the *other* gate leaf which, by the removal of its support, would be swept downstream, if the head were sufficient, and would be followed shortly thereafter by the leaf that was struck, regardless of the type of framing used in the gates.

requires a deeper recess in the wall than a girder gate and this would require a wider wall dividing the two locks. While the masonry need not, on this account, be greatly increased (the extra width being provided largely by back fill) the excavations for the foundations might be very greatly increased throughout the length of the lock and the added expense on this account might be much greater than any possible saving due to the adoption of an arched type of gate. In the case of single locks the increased depth of recess need not cause increased masonry in the wall because what is added at the back need be no greater than what is saved in the recess and the increased excavation on account of the greater width of foundation would occur opposite the gates only and not throughout the length of the lock.

Summarizing the comparison between horizontal arch and beam gates, the writer ventures the opinion that in general arches are more economical and when adequately stiffened against torsion, are quite as satisfactory as girder gates, and that the adoption of the latter type of gates is only justified in special cases where the increased depth of recess would increase the cost of the lock by an amount greater than the saving due to the adoption of a more economical type of framing. This opinion seems to be substantiated by modern practice. The largest gates in this country are those at Keokuk, Sault Ste. Marie and the Cascades Canal and these are all of the arched type. The Panama gates are of the beam type and no doubt the adoption of this type is justified in this case on account of the locks being in pairs, making it desirable not to increase the width of the foundation as would be necessary with arched gates.

Turning now to vertical framing, it is apparent at once that it depends on the ratio of height to length whether or not vertical framing will be more economical than horizontal framing. For instance, no one would claim that vertical framing would be economical for the lofty gates of the Panama Canal, some of which are 82 feet high and only 64 feet long.* On the other hand, vertical framing is clearly indicated for the low-lift locks of the Ohio River where the miter gates adopted will be from 17 to 22 feet high and 62 feet long. The question is then: At what ratio of height to length do the two general types give equal weights? A mathematical analysis of this problem is not altogether satisfactory, because there are too many auxiliary parts to each type of gate which will

*In "Professional Memoirs," Nov.-Dec., 1915, Brig.-Gen. Harry F. Hodges, U. S. A. (under whose direction the Panama gates were designed), in a discussion of an article by the writer in "Professional Memoirs," July-Aug., 1915, brings out the point that it would not have been advisable to adopt vertical framing for the gates of less height even if these particular leaves could have been made lighter by this system of framing, because there would have been a lack of uniformity due to the necessity of using horizontal framing for the higher leaves; this lack of uniformity more than offsetting the saving in weight.

not be shown by general equations. The analysis in *Appendix C* is given, however, for what it is worth.

By this analysis, the weights of horizontal girders and vertical girders are found to be equal when the height is 70 per cent of the length. The figures given, however, do not include a large amount of auxiliary framing such as the vertical diaphragms in horizontally framed gates and auxiliary horizontal members in vertically framed gates. From actual designs, the writer has formed the opinion that the extra framing, not expressed in general equations, is greater with horizontal than with vertical framing and that the ratio found as a result of the analysis in *Appendix C* should be increased to about 1:1. That is, vertical framing and horizontal girders will weigh the same when the height of the gate is equal to its length. When arches are used for the horizontal framing, the weights will be equal when the height is about three-fourths of the length. This latter opinion is based largely on the similarity in weight of the Keokuk and Louisville gates.

A cost-involving element almost as important as the weight is the facility of construction. For three reasons the advantage in this regard should be with vertical framing, whether compared with horizontal beams or horizontal arches. First, a vertically framed gate is built on rectangular lines with an almost entire absence of curved work. Secondly, the erection of that type of gate is much simpler because there are fewer members. Large horizontally framed gates are built up a panel at a time, necessitating careful alignment at each step, while with vertically framed gates, once the few principal members are erected, all other parts may be fitted into place without extraordinary attention to alignment and elevation. Lastly, with the provision for adjustment by means of the adjustable diagonal members, there is no need for extraordinary precision in erection. That it is impossible to use adjustable diagonal members in a horizontally framed gate may, at first sight, seem to be a broad and, perhaps, extravagant statement; but the fact remains that despite the obvious advantage in using such a system, it has never been done with large steel horizontally framed gates, and the writer is not aware of any method by which it could be used advantageously. Without such a system, a gate must be built with such precision and stiffness that when the falsework is removed it will hang in an approximately true position, but with an adjustable diagonal system, this extraordinary care is not required because if the gate is not absolutely true it can be straightened out with the diagonals.

The real test of the desirability of any type of lock gate is its ability to perform successfully the functions for which it is designed. Compared with this consideration, the element of first cost is trivial, because the cost of the lock gates is generally but a small part of the total cost of a lock and it would be folly, indeed, to economize on the first cost of the gates when such economy would result in a continuing loss in efficiency and service.

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So far as the writer has been able to ascertain, there is no marked difference in ease or efficiency of operation between the several types. The cost of maintenance should be less with vertical than with horizontal framing, because of the absence of the large number of small cells into which the latter type is divided by the many intersecting horizontal and vertical members. These cells collect a large amount of deposit in a muddy stream and are difficult of access for cleaning and painting.

In safety or ability to withstand being struck by boats or other shocks, it is not believed that horizontal framing has sufficient advantage (if, indeed, it has any advantage) over vertical framing to influence the choice of type. Generally speaking, when a heavy boat going at high speed hits a lock gate, the latter will be wrecked regardless of its type. The writer is indebted to Gen. Hodges for the statement, in a discussion* of an article by the writer, that vertically framed gates have been known to show a considerable resistance to shocks. When a boat hits one of the leaves of a gate on the down-stream side, while there is a large head on the up-stream side, the effect of the blow is generally to unmiter the leaves and remove the support from the other leaf. Whatever type of framing is used, an accident of this kind will probably result in both leaves being torn away from their fastenings.

There are examples of each type in successful use although horizontal framing so far has seemed to be standard for large gates. The largest vertically framed gates† in use are in the Trans-Atlantic Dock and Bellot Basin at Havre, France. These are for a lock width of 100 feet and are about 35 feet high. In this country the largest gate of this type is in the 80-foot lock at St. Paul, previously mentioned. The ratio of height to length is about 1 to 1. These are the only examples of vertically framing for large locks, so far as known to the writer, but others are to be built in the near future. All of the Ohio River locks, which are not yet built, other than the Louisville lock, are to have vertically framed gates. In these gates the dimensions clearly point to vertical framing, because the locks are 110 feet wide and the height of the gates varies from 17 feet to 22 feet. Vertical framing as applied to small gates has been used very successfully on the 45-foot locks of the Kentucky and Big Sandy Rivers.

At Louisville, while vertical framing for the large lower gate was not approved, this type is to be used for the upper gate and guard gate.‡ Both of these span an opening 110 feet wide. The upper gate is to be about 62 feet long and 25 feet high and the guard gate is of the same length and about 44 feet high.

*"Professional Memoirs," No. 36, Nov.-Dec., 1915.
†Described briefly in General Hodges' "Notes on Mitering Lock Gates."
‡These gates are described in "Professional Memoirs," July-Aug., 1915.

CONCLUSIONS.

Based on the foregoing, the writer draws the following conclusions in regard to the relative merits of vertical framing, horizontal beams and horizontal arches, as applied to lock gates.

(1) There is no very marked difference between the three types so far as efficiency of operation is concerned. The advantage, if any, is with vertical framing because of a probable smaller maintenance cost.

(2) There is little if any advantage of one type over any other type in ability to withstand shocks.

(3) Based on conclusions (1) and (2), it may be said that the choice of type should be controlled generally by the relative costs. Generally speaking, the most economical type should be selected.

(4) Horizontal arches are in general cheaper than horizontal beams. An exception to this rule may occur in the case where the adoption of the arch would result in a large increase in the width of the foundations, on account of the greater depth of the gate recess. This condition does not frequently occur.

(5) Vertical framing will weigh less than horizontal beams when the height is less than the length; and will weigh less than horizontal arches when the height is less than three-quarters the length.

(6) Vertical framing is superior to horizontal framing as regards facility of construction and simplicity of design.

The writer realizes that the above conclusions are rather more favorable to vertical framing than is the general attitude of gate designers toward this type. He does not urge the adoption of this type for all cases but in general believes it has great merits when the dimensions are within the limits stated and believes the advantages of this type of gate have not been sufficiently recognized in the past.

APPENDIX A.

Analysis of Stresses Due to Water Pressure on a Straight Horizontal Girder Lock Gate.

Figure 9 shows a diagram of the forces acting on a straight horizontal girder of a lock gate. The girder is in equilibrium under the forces *AB, BC,* etc., and the end reactions T_1 and T_2.

The flange stresses at any section *X-X,* at a distance equal to x from the end of the gate may be found as follows:

Assume that the metal of the girder is concentrated in the flanges* and take moments about the intersection of the line *X-X* with the downstream flange. The moments acting about this point

*If the common practice of including with the flanges one-eighth of the area of the web is followed the results will check out very closely with those obtained by use of the rigid formula, $f = T/A + My/I$, where $f =$ the unit stress, $T =$ the direct thrust, $M =$ the bending moment, $y =$ the distance to the extreme fibre, and $I =$ the moment of inertia.

are the moment of the end thrust, T_1, and the moments of the "horizontal" and "vertical" components** of the water pressure on the back of the gate. These moments are counteracted by the moment of the stress in the upstream flange. Draw a line connecting the points of contact at the quoin and miter ends of the girder and let the distance of this line from the upper and lower flanges respectively be a and b.

Combining the moments about the intersection of the line X-X with the lower flange, we get,

$$F_1 d = T_1 \,(x \sin \alpha + b \cos \alpha) + pa\,(b + \frac{a}{2}) - \frac{px^2}{2} \ldots\ldots (1)$$

in which $F_1 =$ the total stress in the upper flange, $p =$ the load on the girder per unit of length and the other notation is as shown in Figure 9.

The end reactions, T_1 and T_2, are equal to each other and make equal angles with the axis of the gate; the angle in each case is equal to α, which is the complement of one-half the miter angle.

To determine T_1 and T_2 take moments about the point of contact between the gate and the wall.

$$T_1 L \sin \alpha = \frac{PL}{2}, \text{ from which } T_1 = \frac{P}{2 \sin \alpha}. \quad \text{Placing } P = pL$$

and substituting,

$$T_1 = \frac{pL}{2 \sin \alpha}$$

Substituting the value of T_1 in equation (1) and reducing, the total *compression* in the upper flange is found to be,

$$F_1 = \frac{p}{d}\left(\frac{Lx}{2} + \frac{Lb \cot \alpha}{2} - \frac{x^2}{2} + ab + \frac{a^2}{2}\right) \ldots\ldots\ldots (2)$$

In a similar manner, by taking moments about the intersection of X-X with the upper flange, the total *tension* in the lower flange is found to be,

$$F_2 = \frac{p}{d}\Big)\frac{Lx}{2} - \frac{La \cot \alpha}{2} - \frac{x^2}{2} - \frac{a^2}{2}\Big) \ldots\ldots\ldots (3)$$

In the above equations the first two terms within the parentheses represent the moment of the end thrust, T_1, the third term, $\frac{x^2}{2}$, represents the moment of the "vertical" components of the water pressure to the right of X-X and the remaining terms represent the moment of the "horizontal" components of the water pressure to the right of section X-X.

**"Horizontal" and "Vertical" components are intended to mean those respectively parallel and perpendicular to the downstream flange of the girder. The "horizontal" components are due to the curved back.

APPENDIX B.

Cmparative Weights of Horizontally Framed Lock Gates of the Arched and Beam Types.

It can be proven that the most economical arch subjected to radial loading will be such that the central angle subtended by the two leaves will be about 133°—34′. With this central angle, the length of one leaf along the axis of the arch will be 1.1656 r or .634 B, where r = the radius of curvature and B = the width of the lock between hollow quoins. The arch thrust will be constant throughout the length of the gate and will equal pr, where p = the load per unit of length. The volume of the arch will then be $\frac{prL}{f}$, where L = the axial length of the arch and f = the unit stress. The last expression may be reduced to $V = .345\frac{pB^2}{f}$.

For a beam gate the total stresses in the upper and lower flanges are respectively:

$$F_1 = \frac{p}{p}\left(\frac{Lx}{2} - \frac{x^2}{2} + \frac{Lb \cot \alpha}{2}\right)^* \ldots\ldots\ldots\ldots\ldots (4)$$

$$\text{and, } F_2 = \frac{p}{d}\left(\frac{Lx}{2} - \frac{x^2}{2} - \frac{La \cot \alpha}{2}\right)^* \ldots\ldots\ldots\ldots\ldots (5)$$

These expressions depend on the depth of the girder, the angle α, and the values adopted for a and b. (Fig. 9.) A common value for α is the angle whose tangent is equal to 2/5 or 21°-48′. The depth of the girder may be assumed to be one-tenth of the length, L, and the distance b may be assumed to be one-sixth of d or one-sixtieth of L. The length of the gate, L, will be .538 B, where B = the width of the lock between hollow quoins. Substituting these values in the above equations, the areas of the upper and lower flanges are respectively:

$$a_1 = \frac{5p}{Lf}(Lx - x^2 + .0417\,L^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\text{and, } a_2 = \frac{5p}{Lf}(Lx - x^2 - .2083\,L^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Integrating between the limits $x = 0$ and $x = L$, the volume of the two flanges is found to be $.396\frac{pB^2}{f}$. If the webs are proportioned to resist the maximum shear the web area will be $\frac{pL}{2s}$, where s = the unit shearing stress, usually about ¾ f. Adopting

*Neglecting the small "horizontal" components. See equations (2) and (3), Appendix A.

the latter value and substituting for L, its value in terms of B, the volume of the webs becomes $.193\frac{pB^2}{f}$. If it is assumed that one-eighth of the web area acts with each flange the volume of the two flanges will be reduced by an amount equal to one-quarter of the volume of the webs, or $.048\frac{pB^2}{f}$. The net volume of the flanges, therefore, becomes $\frac{pB^2}{f}(.396 - .048)$ or $.348\frac{pB^2}{f}$. This is about the same as the volume of an arched gate which was found to be $.345\frac{pB^2}{f}$, but the webs of the beam gate have not yet been added. It is clear then that the arches are more economical as to weight than beams.

Appendix C.

Analysis to Determine the Ratio of Height to Length at Which Horizontal Beam Gates and Vertically Framed Gates Will Have the Same Weight.

Assume each upstream flange to be made up of two angles and three cover plates; each cover plate being equal in area to one-sixth of the total flange area.

Assume each downstream flange to be of constant area and designed for the stress near the end of the leaf; say at one-fourth the distance from the end to the center.

Upstream Flange.—The area required at any distance, x, from the end of the leaf is given by equation (6), *Appendix B.*

$$a_1 = \frac{5p}{Lf}(Lx - x^2 + .0417\,L^2) \qquad (6)$$

Substituting in this equation $x = L/2$, the area at the center is found to be, $a_c = 1.4585\frac{pL}{2}$.

To find the distance from the end of the gate to the end of the outer cover plate, substitute for a_1, in equation (6), the area of the flange without the outer cover plate. This area will be five-sixths of the area at the center, or $1.2154\frac{pL}{2}$. Solving, $x = .280\,L$, which is the distance from the end of the gate to the end of the outer cover plate. Similarly, by substituting for a_1, in equation (6), the flange area with two cover plates removed, the end of the middle cover plate is found to be $.188\,L$ from the end of the gate leaf. The third cover plate is assumed to extend the entire length of the gate.

The volume of the upstream flange will, therefore, be:

$$V_1 = 2\left(a_c\frac{L}{2} - .188\frac{La_c}{6} - .280\frac{La_c}{6}\right) = 1.231\frac{pL_2}{f}.$$

Downstream Flange.—The area required at any distance, x, from the end of the leaf is given by equation (7), *Appendix B.*

$$a_2 = \frac{5p}{Lf}(Lx - x^2 - .2083\,L^2) \ldots\ldots\ldots\ldots (7)$$

The area of the flange at one-fourth the distance from the end to the center is found by substituting in equation (7), $x = L/8$, from which the volume of the downstream flange is found to be, $V_2 = .494\frac{pL^2}{f}$.

Webs.—The webs are proportioned to resist the maximum shear, which will be $Pl/2$. The unit shearing stress may be assumed to be three-fourths of the unit stress in tension and compression. The web area will, therefore, be $pL/2 \div \frac{3}{4} f = .6667\, pL/f$. On account of the common practice of assuming that one-eighth of the web area is included with each flange, the net area of the webs will be three-fourths of the above expression, or .5 pL/f. The volume of the webs will be, $V_3 = .5\frac{pL^2}{f}$. The volume of the entire framing will be,

$$V_h = V_1 + V_2 + V_3 = \frac{pL^2}{f}(1.231 + .494 + .5) = 2.226\frac{pL^2}{f}.$$

The unit load, p, is equal to *$1.1111\frac{wh^2}{2}$, in which w is the weight of a cubic unit of water and h is the head acting on the upstream side. Substituting this value of p in the expression of the total volume, the volume of a horizontally framed gate becomes,

$$V_h = 1.237\frac{wh^2L^2}{f} \ldots\ldots\ldots\ldots (8)$$

VERTICALLY FRAMED GATE.

Top Horizontal Member.—This member carries one-third of the total water pressure on the gate; therefore, its weight will be one-third of the weight of a horizontally framed gate, after deducting the excess loads assumed as acting on the horizontally framed gate, due to vertical stiffness, but which is not included in the design of a vertically framed gate. The volume of the top member by these assumptions is equal to,

$$V_4 = \tfrac{1}{3} \times .9 \times 1.237 \times \frac{wh^2L^2}{f} = .371\frac{wh^2L^2}{f}.$$

Vertical Girders.—Assume these to be of uniform section designed for the maximum bending moment and the maximum shear.

*Assuming for convenience that the water surface is even with the top of the gate with the pressure acting on one side only, and that the loads are increased one-ninth on account of vertical stiffness.

The maximum bending moment, under triangular loading occurs at a depth below the surface equal to $\frac{h}{\sqrt{3}}$. The bending moment at this depth will be, $M = .0642\, wh^3L$. Assuming the vertical girders to be of the same depth as the upper horizontal girder the area required in one flange will be $\frac{M}{.1Lf}$, or $.642\,\frac{wh^3}{f}$. The volume of both flanges will be equal to $1.284\,\frac{wh^4}{f}$. The webs are designed for the maximum shear which occurs at the bottom and is equal to $\frac{wh^2L}{3}$. The area required will be equal to the shear divided by $\frac{3}{4}\,f$, or $.444\,\frac{wh^2L}{f}$. Deducting one-fourth of the area of the webs which is assumed to be included in the flanges, and multiplying the remaining area by the height, h, the volume of the webs of the vertical girders is found to be $.333\,\frac{wh^3L}{f}$. The volume of the entire vertically framed gate will be,

$$V_v = .371\,\frac{wh^2L^2}{f} + 1.284\,\frac{wh^4}{f} + .333\,\frac{wh^3L}{f} \qquad \text{(9)}$$

Equating V_h and V_v [equations (8) and (9)] it is found that the two systems of framing will give equal weights when,

$$h^2 + .260\,hL - .674\,L^2 = 0., \text{ or when } h = .701\,L.$$

DISCUSSION.

W. W. DeBerard, M. W. S. E.: I do not exactly understand why you left out the buoyancy chamber. Was it because of the fact that it might become filled with mud? Are they not entirely closed or at times are they opened up?

Mr. Elliott: They have to be opened from the top and at high water our lock is under water, entirely out of sight, and very often the gate would be filled with muddy water of the river, with large quantities of silt. You have no idea how much silt is deposited in that river.

Mr. R. M. Wilson: On that question of maintenance, have you any data or any idea as to what the difference does mean in the different structures?

Mr. Elliott: No. It is just general ideas that I have on the subject. I have no data to prove it for the reason that there have been no gates built of the type I am urging comparable in size with the large horizontal frame gates.

Chairman Lacher: I do not know when we have had a paper that would be so generally instructive, that is, in giving us what is

really new information to most of us. For that reason I would like to give an expression of my understanding of the difference between these two basic types of gates, the horizontal frame and the vertical frame gate. It may be we can get more information from our speaker tonight. A lock is essentially a diaphragm that is placed in a channel or trough which encloses it on three sides. With the horizontal frame gate the support from the lower side is ignored entirely. With the vertical frame gate we avail ourselves of support on all three sides. When the ratio of the height to the width is such that the width is not very large compared to the height there is considerable advantage in using the bottom side, that is, the bed of the channel, as a support for the gate; but if the sides are high, that is, the height is great with respect to the width, as in the larger locks at Panama, there is not much advantage in that because the distance that the pressure must be carried, from the center to the sides, is relatively less than the distance it would be carried from any point near the center of the lock to the bottom. Is that correct?

Mr. Elliott: Yes; that is correct. You have stated it very clearly.

Mr. Wilson: There is just one point. I do not know that it is a fair thing to talk about. I saw the Keokuk locks and those horizontal frames formed pockets, which carried water and the like and it seemed to me a certain amount of rust came in which is going to mean new gates some time in the future. It seems to me in work like that these things could be designed in such a way that the water gets itself clear. There are often engineering structures filled with cobwebs and dirt in a short time. In my younger days we used to do a lot of boating and we used to do the cleaning and repairing of our own boats, and one thing we tried to get in building boats was a clean surface where everything could be easily swept out and cleaned.

Chairman Lacher: Of course, as against that there are certain limitations in structural fabrication, preventing sharp re-entering corners, which would involve additional expense, which would probably be prohibitive. Perhaps Mr. Elliott has some point on that.

Mr. Elliott: It would be hard to make the rounded corners as you see them now used in hospitals, where they have all the corners rounded so that germs can not collect in them. It would be hard to do that with a structure like a bridge built with plates and angles. You could not very well round the corners. I doubt if it would be necessary. I am not familiar with the situation at Keokuk except what I have read and the pictures I have seen in the papers. Of course, a plate girder lying flat is going to have the flanges sticking up over the edge and consequently the upper half of it makes a dish which will collect water, but there is no reason at all why the bottom of this dish should not be perforated so that the water at least will drain off, and if the mud collects on it is a very simple matter, if you have any water pressure, to get in there with a hose and hose it all out.

F. G. Vent, M. W. S. E.: Do you have any trouble with the gates expanding due to the sun shining on them and getting them out of adjustment?

Mr. Elliott: That is a trouble experienced. Theoretically, as Mr. Lacher pointed out clearly, a gate is supposed to receive support on three sides. It is a rectangle supported vertically in the middle at the miter end, at the vertical quoin post and at the still. It is rarely this perfect support will occur on all three sides, due to change of temperature. They are either too long and will meet each other before they meet the sill, or, if they are too short, they will meet the sill before they meet each other. In Panama this problem was solved in a unique way by not having any contact with the sill at all. The gate bears entirely against the other gate and against the wall and the gate does not touch the sill. That is, the structural part of the gate does not touch the sill at all. There is a little space varying, I think, from one-eighth of an inch to perhaps half an inch between the gate and the sill, and at the bottom part there is a rubber flap which is attached to the gate and the water pressure presses it up against the sill and makes the gate water tight. In a vertical frame gate there should be no trouble, because the gates only meet at one point, at the top, provided you have a flexible joint like a rubber cushion, or piece of timber at the miter post. They are bound to bear against the sill because they depend for their stability on the sill.

Mr. DeBerard: You spoke about the crisscross bracing as obviating the necessity of extreme accuracy in the erection of the gate. Suppose the gate was slightly out of adjustment, when you brought it back to adjustment, would you not put initial stresses into some parts of the gate?

Mr. Elliott: Yes, I believe you would.

Mr. DeBerard: Is this too small to be considered?

Mr. Elliott: With an ordinarily good job I doubt whether that would be sufficient to be important. There would be considerable flexibility in a gate which is sixty odd feet long and only six or seven feet wide. It could be bent around considerably without undue strain. However, as you say, initial strain would come on the diagonals or some other part of the gate.

Mr. DeBerard: Just where is the adjustment of these diagonals? It was not shown on the Keokuk gate drawing.

Mr. Elliott: There is no adjustment at Keokuk.

Isham Randolph, M. W. S. E.: There was on the Louisville gate?

Mr. Elliott: Yes.

Mr. DeBerard: There are none shown on the diagram. Are they in behind?

Mr. Elliott: I am afraid I must have run the diagram through too quickly, because there were turn-buckles on our gate, the Louisville gate. There were no turn-buckles whatever on the Keokuk gate.

Mr. DeBerard: There are no adjustments on the Keokuk gate?

Mr. Elliott: No, that gate is incapable of adjustment. It had to be built right to start with.

Carlton R. Dart, M. W. S. E.: My experience has been with small lock gates, but even in their construction I have encountered the problem of more or less indeterminate stresses in horizontal frames. Owing to the lack of continuity in and uniformity of the vertical bracing between the frames, it is very difficult to distribute the loads properly to the various frames. The distribution might be worked out by the principle of least work, but the lack of continuity and uniformity in the vertical frames makes the assumptions and calculations rather uncertain. For that reason I think the vertical framing is very much preferable, and more economical if it can be used.

At the bottom frame of a horizontal frame gate there is a question as to how much load goes to the miter sill. As the author has said, the practice is to design that frame to take the entire load coming against it without assuming any support from the miter sill.

I might mention a type of lock gate that has been designed for the Sanitary District lock at Blue Island. Each pair of gates consists of two sectors, of a cylinder, that is, the horizontal cross-section of each gate in a sector, with a pivot at the center. The pivots are on the sides of the lock and the gates open into sector-shaped recesses in the lock walls. These gates are balanced under all conditions of pressure against them, as all lines of pressure are radial, passing through the pivot. They are expected to operate with a high current velocity through the lock. The purpose of the gates is not primarily for locking but for the controlling of the flow through the Calumet-Sag channel and it is assumed that for this purpose they can be held in any partially open position under all conditions of head against them and of flow through the lock.

President Grant: Is there any gate of that style in operation now?

Mr. Dart: I do not know of any.

President Grant: Who is the designer of this new one?

Mr. Dart: The gate was suggested by Mr. E. L. Cooley. There is a sector dam at Lockport, designed by Mr. Cooley, that is equivalent to one of these sector gates, placed horizontally, with a horizontal hinge or pivot. The gate can be raised or lowered, by water pressure underneath, to control the flow over its crest and drops into a recess beneath it.

E. N. Layfield, M. W. S. E.: Mr. Chairman, one question I would like to ask. Under certain conditions as to dimensions it seems to be economical to use the arch type rather than the beam type, and we are precluded in certain particular cases from doing so because of two locks being side by side. I would like to ask Mr. Elliott if there is any merit in the idea of using in each pair the arch for the outside one and the beam type for the inside one, making the apex perhaps not in the center but perhaps slightly off center.

Mr. Elliott: I never heard any scheme like that proposed before. Offhand I doubt whether it would be justified, even if there were any economy in metal by doing so. It might be that more would be lost by lack of uniformity. General Hodges brought out that point in a discussion of an article which I wrote some time ago, advocating vertical framing. I made the comparison between our gate and the Panama gates and it seemed rather unfavorable to the Panama gates, although I did not intend it in that way. He brought out the point that it would not have been profitable for them to use vertical framing in that case, even where it was most economical for the particular gate under consideration, because that would have destroyed the uniformity of the whole system. They have ninety-two gate leaves in the Panama Canal; and to save a few thousand pounds on one or two of these gate leaves it would not pay to change the design radically. For that reason they picked out the design that was most suited for the largest of the gates and adhered to it throughout. Whether the gate is eighty-two feet high or forty-seven feet high, the girders were interchangeable and made by the same template, and when they got on the job I suppose they could have been used on one gate just as well as they could have been used on another. So likewise with Mr. Layfield's suggestion of using an arch on one side and a beam on the other, I doubt whether that would pay on account of the sacrifice in uniformity of design, even if practical.

Mr. Layfield: It would be impractical in operation, would it, in case it should work out?

Mr. Elliott: No, I think it could be used, if the stresses balanced.

Mr. Randolph: The stresses met by varying the spaces between the girders?

Mr. Elliott: Yes, sir; by varying the spaces rather than the section of the girder.

Murray Blanchard, M. W. S. E.: The statement was made that it would not pay to go to any great expense to provide against the possibility of accidents and that it would pay to take the most economical type of construction and use the money, preferably, to prevent accidents. I was wondering if anything in particular had been done in recent years, especially since the accident at the Soo that tied up the traffic for some time, and whether anything had been done at Panama or Keokuk to provide against serious accidents which might tie up traffic and entail a great deal of expense; if there were any devices or simple precautions or emergency gates provided; if there was any special provision; whether anything had been done in recent years in this line.

Mr. Elliott: The inquiry is very pertinent. Elaborate precautions have been taken at Panama. You will recall the discussion of the advisability of a lock canal,—a lock canal versus a sea level canal. It has been discussed before societies and the importance of providing against accidents was brought out. I think the designers

of the Panama Canal had that in mind when they created and designed so many safeguards at Panama. In the first place, as I understand it, there is a pair of safety gates through which the boat has to pass first and the boat can knock down the safety gates without hurting the lock at all. When it gets by the safety gates,—or maybe before it gets to them, I do not know—it has to pass over safety chains which span the lock and run over sheaves in the lock walls, with counterweights and chains so designed that the chain will sag about ten or fifteen feet and bring the boat to a stop before it strikes the gate. I believe that would be a very effective method of providing safeguards. You could make the chain so stout that it would wreck the boat rather than the gate. It is really the boat's concern if she can not control her engines. It would be better that the boat be wrecked than that the lock be wrecked and possibly damage other craft in the lock.

I can think of a number of other things that might be done, although I do not know of any that have been done. I think spring buffers on the up stream side of a gate would provide a substantial safeguard for the gate, or you could make that part of the gate which is most likely to be hit by a boat heavier than any other part of the gate. In our design we made a practice of guarding against injury by an arbitrary method. We assumed that the effect of a boat hitting the gate is equal to a static load of 120,000 pounds. Where that came from I do not know or whose method it is I do not know, but we always use it.

Mr. Dart: I would like to ask if horizontal sliding gates are used, and, if so, why they were adopted.

Mr. Elliott: There is a very interesting history concerning the horizontal sliding gate or the box-car gate, as it is called. They resemble very much a box-car. They are mounted on wheels and run on a truck transversely to the direction of the lock, and there is a deep recess in the land wall into which this car slides when the gate is open. When it closes it slides out and closes the opening, acting as a gate. Some years ago when the improvements of the Ohio were first considered, the first gate built on the Ohio was at Davis Island, near Pittsburgh, and it is on record that the board of engineers came to the conclusion that the best width of lock would be seventy-eight feet because the low lift in these locks necessitated low gates, and they did not believe it practicable to have longer miter gates of this low height. That is a matter of official record, contained in a government report. But on the adoption of this seventy-eight foot lock the river interests raised some opposition to it. They did not like it and they demanded 110 foot locks. At that time Major Merrill, I believe, of the Corps of Engineers, designed this rolling gate which made the larger locks possible. About two years ago, however, mitering gates were designed for the wide locks, a feat that was formerly considered impossible on account of the small height. It was possible only by the adoption of the vertical framing. Some of these gates are only

seventeen feet high, sixty-two feet long, and it would have been very difficult to build up a string of horizontal girders of that long a span and that low depth and support them, and we finally provided a gate of vertical frame principle. It is true none have been built yet, but the design has been approved. It has been subjected to the scrutiny of many United States engineer officers and the Chief of Engineers and the design has been definitely adopted for all locks that are to be built in the future. Therefore, any of you that go down the Ohio River by water will find some locks controlled by the box-car gate and others by the miter gate.

Mr. Dart: Are those miter gates supported on rollers?

Mr. Elliott: No, sir; free at the miter end. A miter gate without the use of rollers. With a cantilever and with stresses definitely analyzed it is merely a question of putting up the metal to support them. I should say offhand it would be possible to build a miter gate without the support of the roller for any height as low as one-tenth of the span. That would be about the ordinary ratio of depth to length of a cantilever girder. Perhaps that would be a little low. Perhaps one-eighth would be better. But, no doubt, it would be possible to build a gate with a height as low as one-eighth of the span. With a span sixty-two feet long I think you could build a miter gate eight feet high. The deflection, of course, would be cared for by adjustment of the cantilever.

Mr. Randolph: Would that be cared for by erecting a column over the hinge?

Mr. Elliott: Yes, sir. That has been done in some of the older gates.

Major J. C. Oakes: (By letter)—In his paper Mr. Elliott has described clearly and tersely the main differences between the three principal types of mitered lock gates, and, in my opinion, he has performed a service by inviting attention to a type of gate which has heretofore been seldom used, and against which there seems to be considerable prejudice. It is probable that this prejudice is due to conservatism and the slowness with which engineers in general are prone to adopt new types of structures where there are old types that satisfactorily fulfill the requirements. For certain conditions, however, the vertically framed lock gate has a great advantage over the other types in stiffness, economy and material, and ease of erection and maintenance. Owing to the method of framing, it is feasible to use heavy diagonals combined with verticals to form cantilever trusses hung from the quoin posts. By making these diagonals adjustable the whole problem of sag is eliminated, and by using two trusses separated by a proper distance, and firmly connected, great stiffness against warping results. By placing the skin in the proper position, the buoyancy of the gate under pressure is kept less than the weight of the gate.

The locks that are now being constructed in the Ohio River have generally very low lifts, ranging from 7 to 9 feet. The only exception to this is at Louisville, where a single lock, for which

the Louisville gate described by Mr. Elliott was designed, has a normal lift of 35 feet, which may become 42 feet if the lower pool be lost. Previous to the designing of that gate, there had been used at all of the new Ohio River locks, rolling gates which moved on tracks perpendicular to the axis of the locks. When open, the gates are housed in gate recesses extending into the bank from the land side of the lock. At some of the locks, the operation of the gates has been difficult, owing to the filling of the gate recesses by silt and debris during high water, which, in the Ohio River, may be expected many times during each year. In the vicinity of Louisville the lock recesses would be flooded during about 80 days each year, and during such time, the gate recesses might become practically filled with silt, which would prevent the operation of the gates, and, therefore, the locks, until the silt should be removed. Such delays might seriously interefere with navigation and defeat the object of the works of construction.

In addition to the gate described by Mr. Elliott in the paper under discussion, he designed a vertically framed gate for the head of the Louisville lock, where the conditions are similar to those at all of the other locks in the Ohio River. This gate is approximately 25 feet high and 62 feet long (each leaf). The height of the gates at the other Ohio River locks ranges from 17 to 22 feet.

Owing to local conditions it was practically impossible to use the rolling gate and the great width and low lift made it inadvisable to attempt to design a horizontally framed gate for the site. The vertically framed gate fitted the conditions so nicely, and the design was so simple and determinate that there was no trouble whatever in obtaining its approval for the Louisville lock. Later approval of similar designs has been obtained for all new Ohio River locks.

With reference to the disapproval of the design of the gate described in this paper, I may say that I am personally convinced that the gate as designed would be entirely satisfactory if the sill foundation had been satisfactory. The design was practically condemned before it was completed, because of the poor rock foundation. The excavation for the lock was made through shale, hard flinty limestone and magnesia limestone, lying generally in thin horizontal layers, some of the layers being not more than a few inches in thickness. Between these layers there are well developed seams and lenses filled with silt and clay.

As the vertically framed gate transmits to the sill two-thirds of the pressure it withstands, it was not considered safe to adopt that type of gate for that site, particularly as there had been trouble with sills of the existing smaller locks when they were opened in 1871.

Henry Goldmark, M. W. S. E. (By letter): The writer has read Mr. Elliott's paper with much interest, though he does not find himself in agreement with its conclusions as to the relative merits of arched and straight gate leaves.

The earliest iron lock gates were built fully 75 years ago.

but the controversy as to the best shape for such gates had raged with more or less virulence ever since. As early as 1836 the celebrated English engineer, Barlow,* argued in favor of arched leaves, giving essentially the same reasons for preferring them as the author of the present paper.

Since then a large number of metal gates have been built in different countries, the majority of the larger ones being without doubt in the harbor works of Great Britain and the Continent. Quite a number of the earlier foreign gates, including some of considerable size, were of the arched form, but for the past 40 years, as far as known to the writer, very few, if any, large gates of this type have been built, excepting a limited number in the United States. As European engineers have a far more extended experience than ourselves in this class of construction, their action in discarding the curved form should weigh heavily in judging this question.

At the present time English lock gates are almost universally straight on the down stream face, while the up stream side is curved to the arc of a circle of large radius from the quoin to the miter post. The later German gates, such as those originally erected on the Kiel canal, are trapezoidal in shape, the greater part of the two faces being straight and parallel.

In the United States, mainly under the auspices of the Corps of Engineers, U. S. Army, a number of arched gates have been constructed, of which those in the Poe lock at Sault Ste. Marie and in the Cascade lock on the Columbia River are the most important. They have given good satisfaction in service, although being rather narrow, the inspection and painting of the interior compartments have proved difficult. No trouble has arisen from the lack of rigidity which is often ascribed to leaves of this form. The deep recesses in the lock walls which arched leaves make necessary have proved objectionable even in single locks. In the case of twin locks with a common middle wall, the increased cost of the masonry would more than outweigh any possible saving in the metal work.

Even in America the straight leaf seems to be coming to its own. The 46 gates at Panama and those in the latest lock at the Soo, also, it is believed, all the gates in the New York Barge Canal, have faces that are parallel, excepting towards the ends where the upstream face is curved for a short distance to connect with the quoin and miter posts. This shape has great practical advantages. Very little curved work is required in the shop except the bending of the upstream chord angles in the horizontal girders. In the Panama gates, these angles, over 3,000 in number, were bent cold without difficulty and at small expense. The sheathing plates, except some of the heavier gages, did not require to be bent in the shop, but were easily drawn up to the curved chords by field bolting. As

*(Transactions Inst. Civ. Engrs., Vol. 1.)

these leaves are practically rectangular, almost all the vertical frames and many other details are interchangeable, making the work simple and easy to erect. The greater width of the compartments makes the interior inspection easier.

The only advantage claimed for arched leaves is greater economy in first cost. Pound for pound they are much more expensive to build so that a decided saving in weight would be necessary in order to make their total cost less.

The only way to determine the comparative weights accurately is to make detailed designs of a considerable number of gates with complete bills of material. The plans should, as far as possible, differ only in the shapes of the horizontals, similar details being used throughout. Such investigations are, of course, very laborious, but in no other way can reliable results be obtained. Studies of this kind were made by the writer at the suggestion of the late Alfred Noble in 1898-99 for the U. S. Board of Engineers on Deep Waterways and again in 1908 to determine the best shape for the Panama gates. In the former case some 1,500 horizontals were investigated by the writer personally and many others by Mr. H. S. Woodard, his assistant and successor. Gates up to 80 feet in height tor locks 60, 70 and 80 feet wide were included in these studies. When designing the Panama gates, locks 100, 110 and 120 feet wide were considered, the leaves being as much as 80 feet in height. A wide range in lock widths and heights was thus fully covered.

The results are given in the report of the above mentioned Board and in the paper on the Panama gates by the writer, which was referred to by the author in his discussion.

The conclusions arrived at were the following:

(1) Taking the horizontal frames (girders or arches) by themselves, for those under heavy hydrostatic loads, the arches proved to be considerably lighter than the girders, in some cases as much as 20 to 25 per cent.

(2) For horizontals near the top of the gates and for all other frames under comparatively light loading, the difference was small and in many cases non-existant.

(3) Taking the gate, *as a whole,* the saving in weight was very much less than for the horizontal alone; in fact, it usually proved to be quite moderate even for large gates. Taking all the Panama gates into account, the difference in weight was only 6 per cent in favor of arched leaves.

(4) The cost of construction per pound is so much greater for curved gates that it entirely wiped out this theoretical advantage and made them actually more expensive. This statement was found to be true for all the lock widths from 60 to 120 feet and for all heights. The relative costs per pound used were based on the judgment of several contractors of wide experience, to whom detailed alternative plans were submitted by the writer. His later experience at Panama has convinced him that the difficulties of building arched gates were much underestimated by these experts. At any

rate, all those connected with the work on the Isthmus were very glad that the difficult erection was not made still harder by having to handle curved leaves.

As stated above, the method used by the author for showing the greater economy of arched gates is practically identical with that employed by previous writers who hold the same views. It consisted in obtaining from the stresses, theoretical figures for the volumes and weights of horizontal girders and arches and from these to draw conclusions as to the relative economy of the two types. It disregards the fact that in a large part of the horizontals it is necessary, for practical reasons, to use cross sections much larger than those given by the strain sheet. The method is, therefore, incorrect, even as regards the horizontal frames and is still more unreliable for the leaf as a whole, as it does not take into account the other parts which usually constitute over two-thirds of the total.

As is well known, such short and easy ways of arriving at economical designs have long been discarded by experienced bridge engineers as absolutely unreliable in practice. This was pointed out to the writer very forcibly by Mr. Noble before the investigations above mentioned were undertaken.

After all, the cost of the gates constitutes only a small part of the total cost of a lock, and extreme economy is less important than simple forms of construction which leads to easy operation and maintenance. The more complicated designs advocated by the author, even if they were somewhat cheaper, would, therefore, appear undesirable in comparison with the well-tried girder gate with horizontal framing.

Closure.

Mr. Elliott: The writer has been very much interested in the new type of gate described by Mr. Dart. The sector has been used frequently for movable dams and in such cases it revolves about a horizontal axis, but its use for lock gates, revolving about a vertical axis, is original so far as known to the writer. This gate has certain advantages for the special conditions encountered in the Sanitary District, which could not have been obtained readily with any other type of gate. Because of the balanced pressures, it will be possible to operate the gate with the full head acting against it. It can be held at any intermediate position and by varying the size of the aperture between the two leaves, a practically uniform rate of variation of the level of the water surface in the lock may be obtained. This uniformity of flow is not obtainable with mitering lock gates because the water is admitted through valves and it is practically impossible to vary the valve area so that the water will enter at a uniform rate, while the head is constantly decreasing. In the Louisville lock, for instance, it is assumed that the maximum rate of change in the level of the water surface, consistent with the safety of boats in the lock, is 6 feet per minute. If this rate of variation is safe and could be maintained steadily

the lock could be filled in six minutes. But it would require an enormous valve area to maintain this rate while the head decreases. Although the maximum rate of rise is 6 feet per minute, the average will be only about 2 feet per minute and the time required to fill the lock will be nearly 20 minutes. With the sector gate no other valves are used—the gate itself acts as a valve—and by opening it slowly, the area through which the water flows may be made to increase while the head decreases, thus approximating a uniform rate of flow into the lock and saving time in operation.

The sector gate, however, has certain limitations that preclude its general use on navigable streams. It requires much deeper recesses in the lock walls than any type of mitering gate and for that reason might increase largely the cost of the lock walls. For high heads the greater pressure on the hinge might interfere with the operation of the gate. It is also doubtful whether the gate could be made as water-tight as other types.

In the writer's opinion, Major Oakes has overestimated the importance of the sill foundation for vertically framed mitering lock gates. It is true that a large part of the pressure on the gate is supported by the sill, but it is a simple matter to arrange that this pressure on the sill be transmitted into the lock walls. With all mitering gates the sill is generally imbedded in concrete and if this is designed so that it will act as an arch between the two lock walls acting as abutments the sill pressure will be cared for without placing any confidence in the rock or other foundation under the sill and in this case the walls will receive exactly the same amount of thrust as with a horizontally framed gate, the only difference being that in one case a part of it is transmitted into the walls by means of a masonry arch and in the other case by the steel girders of the gate. The leakage and scour under the sill is, of course, the same with either type of gate.

To illustrate the ease with which a vertically framed gate may be erected and adjusted, the writer might mention a gate of this type which has been built since this paper was written. The gate referred to is the guard gate at the upper end of the new lock of the Louisville and Portland Canal at Louisville. This is not the same gate as that shown in Fig. 4, in which case vertical framing was not approved, but is another gate in the same lock. The gate referred to is shown in Fig. 10. The two leaves of this gate were erected and bolted up in eleven working days by a force of eighteen men. The bottom girder was leveled up by the grade party and thereafter no alignment or leveling was done until every piece of metal was in place. After the gate had been assembled and bolted up, the false work was removed and the gate swung on its own hinges. With two 90-ton jacks and the adjustable diagonals, one leaf of the gate was plumbed and straightened in less than four hours. After adjustment there was no perceptible sag or warp in the gate. The reaming and riveting is now in progress. With large horizontally framed gates, such as those at Panama and

Keokuk, there is no way of adjusting or twisting the gate after all the metal is in place and, therefore, each piece must be placed with care and lined up carefully as it goes into the work.

Mr. Goldmark's notes as to the comparative costs of straight and arched gate leaves are particularly valuable because of his experience with both types of gates.

So far as the girders themselves are concerned it is probably true that the arched form will be more expensive, pound for pound, than the straight backs, even when the latter are curved near the ends. The other parts of the gate, such as the sheathing, vertical

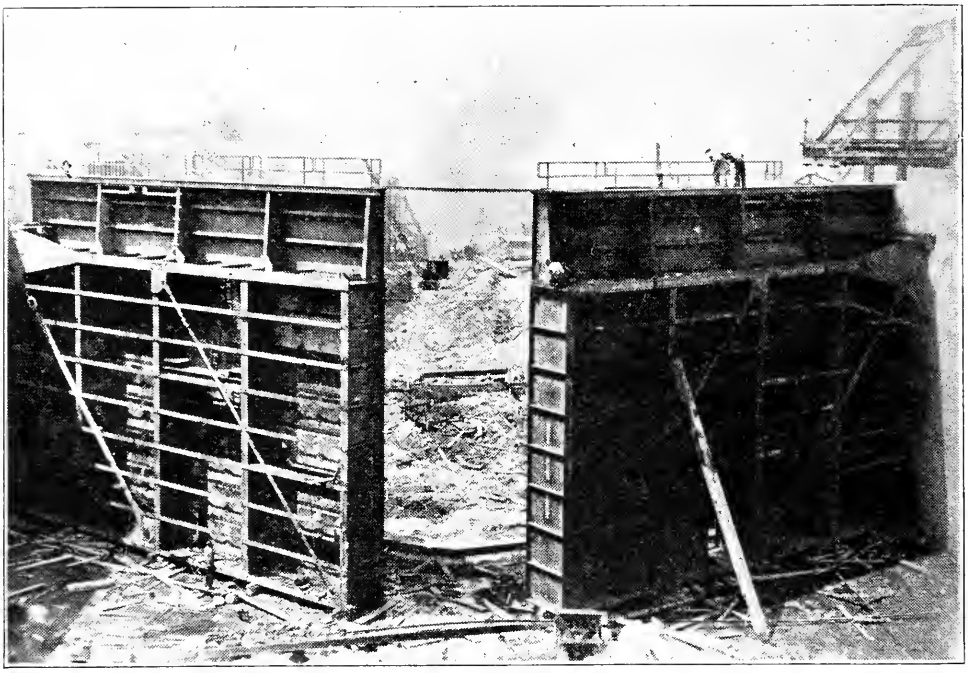

Fig. 10

diaphragms, etc., should be no more expensive in the arched form. The sheathing for an arched gate can be drawn to the proper curve by bolting even more readily than was the case with the Panama gates, as noted by Mr. Goldmark, because the radius of curvature is greater with an arched gate than that of the curved ends of a beam gate. The vertical diaphragms are readily interchangeable from leaf to leaf and from place to place in the same leaf if the arch is of the same depth throughout.

The writer agrees with Mr. Goldmark that actual designs with estimates of weights form a better method of comparing relative weights of different types of gates than theoretical analysis. Although the writer used some of the latter in his paper his conclusions as to the relative weights of arches and beams were based largely on a comparison between the Keokuk and smaller Panama gates. Although these two gates are about the same size and support about the same water pressure, the Panama gate is about

50 per cent heavier than the Keokuk gate. The writer also designed gates of both types for the Louisville lock, and found about the same disparity in weight in favor of the arch type. A similar comparison between the arch and straight girder type was made for the Keokuk lock; in fact, a complete design of the straight girder was made before the adoption of the arch gate, and the former type was rejected because of excessive weight. These facts seem conclusive to the writer as indicating a somewhat larger difference in weight between the two types than that which Mr. Goldmark found in his investigations.

As to vertical framing, it depends entirely on the ratio of height to length, whether this type is more or less economical than horizontal framing. In facility of fabrication and erection, the advantage is all with vertical framing.

The writer recently designed a pair of gates for a dry dock 80 feet wide. In determining the relative weights of horizontal and vertical framing, a complete design of a vertically framed gate was made and the weight was compared with the weight of a horizontally framed gate, as derived from the formula contained in the report by Mr. S. H. Woodard in the Report of the U. S. Board of Engineers on Deep Waterways, referred to by Mr. Goldmark. This formula was derived by making actual designs and detailed estimates of 125 different cases, plotting these weights and fitting equation to the curves. The equation for an 80-foot lock is as follows: $W = (78.33 + .222\,D)\,H^2 + (1633.5 + 65.55\,D)\,H + (40000 + 3000\,D)$ in which, W = the weight of the gate in pounds, D = depth of water in feet on the sill on down-stream side of gate, and H = head in feet acting on the gate. For the gate referred to, $D = O$, and $H = 19$ feet. Substituting these values in the equation, the weight per leaf of the horizontal beam gate would be 99,000 pounds per leaf. The actual shipping weight of the vertically framed gate of the same size is 60,000 pounds per leaf, showing a saving of 39 per cent by using vertical framing. In simplicity of design and facility of erection, this gate is far superior to the horizontal framing. This gate is noteworthy also because it is fitted into a recess in the wall which was intended and used for many years for a horizontally framed gate.

Of course, these figures are not conclusive for a general comparison between vertical and horizontal framing, but they show the economy resulting from the use of vertical framing in this particular instance and emphasize the importance of considering this type of gate when the dimensions are such as to make it economical.

Having had this successful experience with vertical framing, the writer is not willing to adhere to horizontal framing in all cases merely because that type has been favored for so many years in this country and Europe. In this paper and discussion he has attempted to show that vertical framing may be used advantageously in some cases and that tradition alone is not sufficient cause for its rejection.

October, 1916

COMPARATIVE DESIGNS OF OFFICE BUILDINGS

By Fred Ruchti, M. W. S. E.

Presented June 12, 1916.

INDEX.

INDEX TO EXTRACTS FROM BUILDING ORDINANCES.

INTRODUCTION.

There are many architectural companies in the country who make a specialty of office building designs. The larger of these companies have had a number of years' experience in this class of work, and have developed their designs so that at the present time it is probably true that they are securing a maximum of efficiency with an economical expenditure of material. Each of the engineering or architectural companies has to some extent been working independently of the other, adhering to certain features and details characteristic to its office. Naturally, the designs of the different offices will vary considerably, some embodying details which are of the best construction, whereas other designs will contain certain features which could be used to advantage on all structures. Probably few, if any, will contain all of the satisfactory elements of a good economical design. This is not intended as a criticism, as such conditions are merely the natural outgrowth of the development of independent designs and ideas.

The object of this paper is to review and collect some of the more important details of the structural steel of office buildings in the city of Chicago. The writer will confine his attention to the detailing, fabrication and erection of these details, advancing ideas to show that these details can be often handled in a more uniform manner resulting in more standard methods. It is with this thought in view that he makes specific recommendation in instances where a particular type appears to be desirable.

The paper has been for convenience divided into the various subdivisions and treats briefly of foundations, retaining walls, columns, floors and floor construction, party walls, wind bracing details; spandrel beams, interior steel stacks and roofs. For convenience to the designer the writer has included the pertinent portions of the Chicago Building Ordinance as it applies to each of these subjects.

In the subject of wind bracing details, the writer has observed a rather wide diversity of opinion in the manner of handling such details. Such connections in their best form add considerably to the cost of the steel frame. They must, however, be made in order to obtain the desired amount of stability, and he has recommended such types as will prove fairly economical for construction. It has been thought advisable to include also some method or proposed method of computing the details that the designers wish, as regards rigidity, may be carried out.

The writer wishes to express his appreciation for the suggestions and assistance given to him by Mr. Albert Reichmann, and Mr. J. H. Hoff, Members Western Society of Engineers, and also Mr. G. C. Haun and Mr. F. M. Christensen, who assisted materially in the preparation of this paper. The article on wind bracing was written by Mr. Haun.

EXTRACTS FROM CHICAGO BUILDING ORDINANCE.

GENERAL.

569. *Skeleton Construction.* (a) The term "Skeleton Construction" shall apply to all buildings wherein all external and internal loads and stresses are transmitted from the top of the building to the foundations by a skeleton or framework of metal or reinforced concrete.

(b) In metal frame skeleton construction the beams and girders shall be riveted to each other at their respective junction points. If columns made of rolled iron or steel are used, their different parts shall be riveted to each other, and the beams and girders shall have riveted connections to unite them with the columns. If cast iron columns are used, each successive column shall be bolted to the one below it by at least four bolts not less than ¾-inch in diameter, and the beams and girders shall be bolted to the columns. Bolt holes in flanges for connections from column to column shall be drilled. At each line of floor or roof beams, lateral connections between the ends of the beams and girders shall be made in such manner as to rigidly connect the beams and girders with each other in the direction of their length.

(c) All steel trusses shall be riveted and the steel work in buildings more than 100 feet high and in a building whose height exceeds twice its width shall be riveted.

(d) Wherever it is found impossible to rivet connections as herein described and such connections are bolted, cold rolled or turned bolts of exact fit and diameter in reamed holes may be used in place of rivets with the same allowable stresses as field driven rivets.

(e) All structural members which are temporarily bolted together shall be well bolted in every alternate hole.

(f) After the bases or base plates and columns have been set in place, both shall be protected by a covering of cement concrete applied direct to the metal, measuring not less than two and one-half inches thick from the extreme projection of the metal, filled solid into all spaces, and forming a continuous concrete mass from the grillage or other foundations to an elevation six feet above the floor level nearest the column base plate or column stool.

(g) All metal shall be clean and shall be free from all loose rust and scale, and all metal except that to be embedded in concrete shall be protected with at least two coats of metal protecting paint.

(h) All structural details and workmanship shall be in accordance with accepted engineering practice.

(i) All trusses shall be held rigidly in position, both temporarily and permanently, by efficient lateral and sway bracing.

620. *Fire-proof Material.* The materials which shall be considered as filling the conditions of fire-proof covering are: First, burnt brick; second, tiles of burnt clay; third, approved cement concrete; fourth, terra cotta.

622. *Incombustible Material.* The following materials shall be considered as incombustible material: A metal or fire-resisting glass not less than one-quarter of an inch in thickness, metal, plastering on metal lath and metal studding, plaster blocks, stone, granite, marble, approved cinder concrete or one of the fire-proof materials described in this chapter.

623. *Walls—Enclosing in Buildings of Steel Skeleton Construction.* If buildings are made of fire-proof construction, and have skeleton construction so designed that their enclosing walls do not carry the weight of floors or roof, then their walls shall not be less than twelve inches in thickness; provided, such walls shall be thoroughly anchored to the iron skeleton, and whenever the weight of such walls rests upon beams or columns, such beams or columns shall be made strong enough in each story to carry the weight of wall resting upon them without reliance upon the walls below them. All walls shall be of fire-proof or incombustible material.

624. *Columns—Exterior.* (a) All iron or steel used as vertical supporting members of the external construction of any building exceeding fifty feet in height shall be protected against the effects of external change of temperature, and of fire by a covering of fire-proof material consisting of at least four inches of brick, hollow terra cotta, concrete, burnt clay tiles, or of a combination of any two of these materials, provided that their combined thickness is not less than four inches. The distance of the extreme projection of the metal, where such metal projects beyond the face of the column, shall be not less than two inches from the face of the fire-proofing; provided, that the inner side of exterior columns shall be fire-proofed as hereafter required for interior columns.

(b) Where stone or other incombustible materials not of the type defined in this ordinance as fire-proof material is used for the exterior facing of a building, the distance between the back of the facing and the extreme projection of the metal of the column proper shall be at least two inches, and the intervening space shall be filled with one of the fire-proof materials.

(c) In all cases, the brick, burnt clay, tile or terra cotta, if used as a fire-proof covering, shall be bedded in cement mortar close up to the iron or steel members and all joints shall be made full and solid.

625. *Columns—Interior.* (a) Covering of interior columns shall consist of one or more of the fire-proof materials herein described.

(b) If such covering is of brick it shall not be less than four inches thick; if of concrete, not less than three inches thick; if of burnt clay tile, such covering shall be in two consecutive layers, each not less than two inches thick, each having one air space of not less than one-half inch, and in no such burnt clay tile shall the burnt clay be less than five-eighths of an inch thick; or if of porous clay solid tiles, it shall consist of at least two consecutive layers, each not less than two inches thick; or if constituted of a combination of any two of these materials, one-half of the total thickness required for each of the materials shall be applied, provided that if concrete is used for such layer it shall not be less than two inches thick.

(c) In the case of columns having an "H"-shaped cross section or of columns having any other cross section with channels or chases open from base plates to cap plates on one or more sides of the columns, then the thickness of the fireproof covering may be reduced to two and one-half inches, measuring in the direction in which the flange or flanges project, and provided that the thin edge in the projecting flange or arms of the cross sections

does not exceed three-quarters of an inch in thickness. The thickness of the fireproof covering on all surfaces measuring more than three-quarters of an inch wide and measuring in a direction perpendicular to such surfaces shall be not less than specified for interior columns in the beginning of this section, and all spaces, including channels or chases between the fireproof covering and the metal of the columns, shall be filled solid with fireproof material. Lattice or other open columns shall be completely filled with approved cement.

626. *Columns—Wiring Clay Tile On.* (a) Burnt clay tire column covering shall be secured by winding wire around the columns after the tile has all been set around such columns. The wire shall be securely wound around tile in such manner that every tile is crossed at least once by a wire. If iron or steel wire is used it shall be galvanized and no wire shall be less than number twelve gauge.

(b) In places where there is trucking or wheeling, or handling of packages of any kind, the lower five feet of every column encased with hollow tile shall be incased in a protective covering of No. 16 U. S. Gauge steel embedded in concrete.

631. *Spandrel Beams, Girders, Lintels.* The metal of the exterior side of the spandrel beams or spandrel girders of exterior walls, or lintels of exterior walls, which support a part of exterior walls, shall be covered in the same manner, and with the same material as specified for the exterior columns in this ordinance; provided, however, that shelf angles connected to girders by brackets or projections of girder flanges not figured as part of the flange section may come within two inches of the face of the brick or other covering of such spandrel beams, girders or lintels. The covering thickness shall be measured from the extreme projection of the metal in every case.

632. *Beams, Girders and Trusses—Coverings of.* (a) The metal beams, girders and trusses of the interior structural parts of a building shall be covered by one of the fireproof materials hereinbefore specified so applied as to bé supported entirely by the beam or girder protected, and shall be held in place by the support of the flanges of such beams or girders and by the cement mortar used in setting.

(b) If the covering is of brick, it shall be not less than four inches thick; if of hollow tiles or if of solid porous tiles, or if of terra cotta, such tiles shall be not less than two inches thick; applied to the metal in a bed of cement mortar; hollow tiles shall be constructed in such a manner that there shall be one air space of at least three-fourths of an inch by the width of the metal surface to be covered within such clay coverings; the minimum thickness of concrete on the bottom and sides of metal shall be two inches.

(c) The top of all beams, girders and trusses shall be protected with not less than two inches of concrete or one inch of burnt clay bedded solid on the metal in cement mortar.

(d) In all cases of beams, girders or trusses, in roofs or floors, the protection of the bottom flanges of the beams and girders and so much of the web of the same as is not covered by the arches shall be made as hereinbefore specified for the covering of beams and girders. In every case the thickness of the covering shall be measured from the extreme projection of the metal, and the entire space or spaces between the covering and the metal shall be filled solid with one of the fireproof materials excepting the air spaces in hollow tile.

(e) Provided, however, that all girders or trusses, when supporting loads from more than one story, shall be fireproofed with two thicknesses of fireproof material or a combination of two fireproof materials as required for exterior columns in this ordinance, and each covering of fireproof material shall be bedded solid in cement mortar.

541. *Allowable stresses in pounds per square inch in steel and iron.*

	Rolled Steel	Cast Steel	Wrought Iron	Cast Iron
Tension on net section................	16,000	16,000	12,000	......
Maximum compression on gross section	14,000	14,000	10,000	10,000
Bending on extreme fibre..............	16,000	16,000	12,000	......
Bending on extreme fibre tension......	......	......	......	3,000
Bending on extreme fibre compression..	......	......	......	10,000
Bending on extreme fibres of pins.....	25,000	......	......	......
Shear: shop-driven rivets and pins....	12,000	......	......	......
Shear: field-driven rivets..............	10,000	......	......	......
Shear on rolled steel shapes...........	12,000	......	......	......
Shear plate girder webs; gross section..	10,000	......	......	......
Shear on brackets.....................	......	......	......	2,000
Bearing, shop-driven rivets and pins...	25,000	......	......	......
Bearing, field rivets..................	20,000	......	......	......

543. *Riveting—Tension.* (a) In proportioning tension members the diameter of the rivet holes shall be taken one-eighth of an inch larger than the nominal diameter of the rivet.

(b) In proportioning rivets the nominal diameter of the rivet shall be used.

(c) Pin-connected riveted tension members shall have a net section through the pin-hole at least 25 per cent in excess of the net section of the body of the member and the net section back of the pin-hole, parallel with the axis of the member, shall not be less than the net section of the body of the member.

544. *Plate Girders—Flanges—Compression.* (a) Plate girders shall be proportioned either by the moment of inertia of their net section, or by assuming that the flanges are concentrated at their centers of gravity and a unit stress used such that the extreme fibre stress does not exceed 16,000 pounds per square inch, in which case one-eighth of the gross section of the web, if properly spliced, may be used as flange section.

(b) The gross section of the compression flanges of plate girders shall not be less than the gross section of the tension flanges; nor shall the stress per square inch in the compression flange of any beam or girder of a longer length than 25 times the width exceed $20{,}000 - 160\frac{L}{B}$ (L and B both in inches).

In which formula

L equals unsupported distance, and

B equals width of flange.

(c) The flanges of plate girders shall be connected to the web with a sufficient number of rivets to transfer the total shear at any point in a distance equal to the effective depth of the girder at that point combined with any load that is applied directly on the flanges.

(d) Webs of plate girders shall be provided with stiffeners over all bearing points, under all points of concentrated loading and elsewhere when required by good engineering practice.

546. *Working Values for Reinforced Concrete.*

Mixture	Uutimate compressive strength pounds per square inch. (U)	Ratio of Es to Ec (R)
1–1 –2	2,900	10
1–1½–3	2,400	12
1–2 –4	2,000	15
1–2½–5	1,750	18
1–3 –7	1,500	20

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Mixture is given in the order of: cement, sand and broken stone, gravel or slag.

Es = modulus of elasticity of steel: Ec = modulus of elasticity of concrete.

547. Tensile strength in steel, 18,000 pounds per square inch.

Compressive stress in steel shall not exceed the product of the compressive stress in the concrete multiplied by the ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete.

Direct compression of concrete......................	$\frac{U}{5}$
Bending stress in extreme fiber of concrete..........	.35U
Diagonal tension of concrete........................	$\frac{U}{50}$
Vertical shear with properly reinforced webs.........	$\frac{U}{15}$

547. *Bond Stress of 1-2-4 Concrete.*

	Pounds per square inch
On plain round or square bars of structural steel..............	70
On plain round or square bars of high carbon steel...........	50
On plain flat bars, ratio of sides not greater than 2 to 1......	50
On twisted bars, one complete twist in eight diameters........	100
On deformed bars	100

All reinforcing steel shall be entirely inclosed by the concrete, and shall nowhere be nearer the surface of the concrete than 1½ inches for columns, 1½ inches for beams and girders, and ½-inch, but not less than the diameter of the bar, for slabs.

The longitudinal steel in beams and girders shall be so disposed that there shall be a thickness of concrete between the separate pieces of steel of not less than one and one-half times the maximum sectional dimensions of the steel.

FOUNDATIONS.

528. *Materials.* Foundations shall be constructed of stone gravel or slag concrete, dimension stone or rubble stone, sewer or paving bricks, iron or steel imbedded in concrete or piles, or a combination of any of the same. All masonry foundations shall be laid in cement mortar.

All foundations shall be protected against the effects of frost, and cement mortar which has been affected by frost shall not be used in building operations.

530. *Piles.* Where pile foundations are used the Commissioner of Buildings may require auger borings of the soil to be made to determine the position of the underlying stratum of hard clay or rock. The heads of the piles shall be protected against splitting while they are being driven.

The piles shall be sawed off to a uniform level at least one foot below Chicago datum after being driven, and the heads shall be imbedded in concrete or covered with a grillage so proportioned that in the transmission of the load from the structure to the pile, the stresses in the materials shall not exceed that prescribed in the ordinance. The top of timber grillage shall be at least one foot below Chicago datum.

(Chicago datum is about fourteen feet below the surface of the streets in the downtown district. It corresponds to the low water level of Lake Michigan in 1847, and is about 579 feet above mean sea level in New York.)

(b) The center of gravity of a pile foundation shall coincide with the center of gravity line of the load or loads which it carries.

(c) No pile of less than six inches diameter at small end shall be used.

(d) The safe load on a pile shall be determined by and shall not exceed the following formula:

$$P = \frac{2\ Wh}{S + \frac{1}{10}} \text{ for steam hammer.}$$

$$P = \frac{2\ Wh}{S + 1} \text{ for drop hammer.}$$

S = set in inches,
h = fall in feet,
w = weight of hammer,
P = safe load in pounds.

(e) The maximum load on a timber pile shall not exceed 50,000 pounds.

(g) Plans for pile foundations shall be submitted to Commissioner of Buildings for approval and shall specify the least diameter of small end of piles, and no piles with smaller diameter of points than that specified for the job shall be used.

531. *Concrete Piles.* (a) Where concrete piles are used, test piles shall be driven and loaded under the general direction of the Commissioner of Buildings.

(b) The allowable compression on concrete piles shall not exceed 400 pounds per square inch at a section six feet from the surface of the ground in immediate contact with the pile.

(c) Tests shall be made on at least two piles in different locations, and as directed by the Commissioner of Buildings, not less than three piles to be driven for each test. The pile to be loaded to be driven first, the second pile to be driven within six hours of the driving of the first, the third pile to be driven within twenty-four hours after the first. The two latter shall each be driven with centers not to exceed twice the greatest diameter of pile, from the center of the test pile.

(d) The tests shall not be started until at least ten days after the piles to be loaded are driven. The piles shall be loaded with twice the proposed carrying load of the piles.

(e) The settlement shall be measured daily until twenty-four hours shows no settlement.

(f) One-half of the test load shall be allowed for the carrying load, if the test shows no settlement for twenty-four hours and the total settlement has not exceeded one one-hundredth of an inch multiplied by the test load in tons.

525. *Soil Pressure.* (a) If the soil is a layer of pure clay at least fifteen feet thick, without admixture of any foreign substance other than gravel, it shall not be loaded to exceed 3,500 pounds per square foot. If the soil is a layer of pure clay at least fifteen feet thick and is dry and thoroughly compressed, it may be loaded not to exceed 4,500 pounds per square foot.

(b) If the soil is a layer of firm sand fifteen feet or more in thickness, and without admixture of clay, loam or other foreign substance, it shall not be loaded to exceed 5,000 pounds per square foot.

(c) If the soil is a mixture of clay and sand, it shall not be loaded to exceed 3,000 pounds per square foot.

526. *Foundations in Wet Soil.* In all cases where foundations are built in wet soil, it shall be unlawful to build same unless trenches in which the work is being executed are kept free from water by bailing, pumping or otherwise, until after the completion of work upon the foundations and

until all cement has properly set. In all cases a connection with the street sewer shall be established before beginning the work of laying foundations.

527. *Foundations—Where not permitted—Depth below surface—Independent of underground construction owned or controlled by the city.* Foundations shall not be laid on filled or made ground or on loam, or on any soil containing admixture of organic matter, and must rest on hard, sound soil. Foundations shall, in all cases, extend at least four feet below the finished surface of the ground upon which they are built, unless footings rest on bed rock.

(b) Foundations shall, in all cases, extend at least four feet below the surface of the ground upon which they are built, and in the case of all buildings one hundred feet or more in height, foundations shall extend at least to the depth drained by the street sewer in the adjacent streets or alleys; but if such sewers are at a greater depth than ten feet below the sidewalk grade, such foundations need not extend to a greater depth than ten feet, provided that sound, hard soil is found at that depth.

(c) Every building forty feet or more in height, hereafter erected, which is located adjacent to any street or alley, containing any then existing water main, water tunnel, sewer, conduit, tunnel subway or other underground construction, owned or controlled by the city, shall be so constructed that the foundation or superstructure thereof shall not be supported in whole or in part by any such underground construction.

533. *Allowable stresses.* Allowable stresses in pounds per square inch on plain concrete and stone masonry shall not exceed the following:

Coursed rubble—Portland cement mortar	200
Ordinary rubble—Portland cement mortar	100
Coursed rubble—lime mortar	120
Ordinary rubble—lime mortar	60
First-class granite masonry—Portland cement mortar	600
First-class lime and sandstone masonry—Portland cement mortar	400
Portland cement concrete, 1–2 –4 mixture; machine mixed	400
Portland cement concrete, 1–2 –4 mixture; hand mixed	350
Portland cement concrete, 1–2½–5 mixture; machine mixed	350
Portland cement concrete, 1–2½–5 mixture; hand mixed	300
Portland cement concrete, 1–3 –6 mixture; machine mixed	300
Portland cement concrete, 1–3 –6 mixture; hand mixed	250
Natural cement concrete, 1–2 –5 mixture	150

Loads. The entire dead load and the percentage of live load on basement columns, piers and walls shall be taken in determining the stress in foundations.

(NOTE:—Proportion of live load on columns is given under columns.)

518. (a) The entire dead load and not less than the following proportion of the percentage of live load on the basement columns, piers and walls shall be taken in determining the number of piles for foundations and the area of concrete caissons.

Department stores, light factories, warehouses, stables and garages (ground area greater than 500 square feet)	75%
Office buildings, hotels, clubs, residences, lodging houses, tenement and apartment houses, hospitals, jails, police stations, asylums, houses of correction and detention, houses for aged and decrepit, garages and stables (ground area less than 500 square feet	50%
Churches, schools, lodge halls, dance halls, banquet halls, skating rinks, assembly halls, exhibition halls, theaters, vaudeville houses, moving picture houses, grandstands, amusement parks, baseball and athletic parks	25%

In all foundations, eccentric loading must be provided for.

FOUNDATIONS.

The foundations of nearly all of the larger buildings constructed in the loop district within the last fifteen years are carried down to bed rock. In a few cases, where the buildings are of moderate heights, the foundations rest on a hardpan which lies some distance above bed rock. Pile foundations are used for some of the lower buildings, and spread footings for the less important buildings only.

Bed rock in the loop district lies on the average from 85 to 95 feet below city datum or from 100 to 110 feet below the surface of the streets. This bed rock is overlain with a variety of soils, chief of which is a soft blue clay. In some locations a hardpan of varying thickness overlies the bed rock, and large boulders are often found in these overlying soils.

When the foundations rest on bed rock or on hard pan, the column footings are carried down in the form of cylindrical concrete piers. These piers are constructed by the usual open well process, the timbering being placed as the excavation proceeds. The timbering generally consists of matched timber with the dimensions of about 3 in. by 6 in. and is usd in lengths from 4 to 6 feet. This timbering is placed in a vertical position in the well and is braced by circular steel bands. As the excavation proceeds, one section after another of this lagging is placed.

In some cases the footings are spread in order to give a larger bearing area on the hard pan or rock. This is done by undercutting the excavation a short distance above the bottom of the pier.

The lagging and the steel bands are left in place and form a complete form for the entire pier. The surface of the bed rock is properly prepared and the concrete is then poured. This pouring is usually carried on continuously throughout the entire height and the pier is brought to its proper elevations at one operation.

The two following sketches are typical drawings of these cylindrical concrete piers: Figure 1 and Fig. 2. These piers vary from 4 ft. 0 in. to about 12 ft. 0 in. in diameter.

The piers are not reinforced, though some designers prefer to reinforce a small portion near the top and to tie the tops of these piers together with a series of concrete struts as shown in Fig. 1.

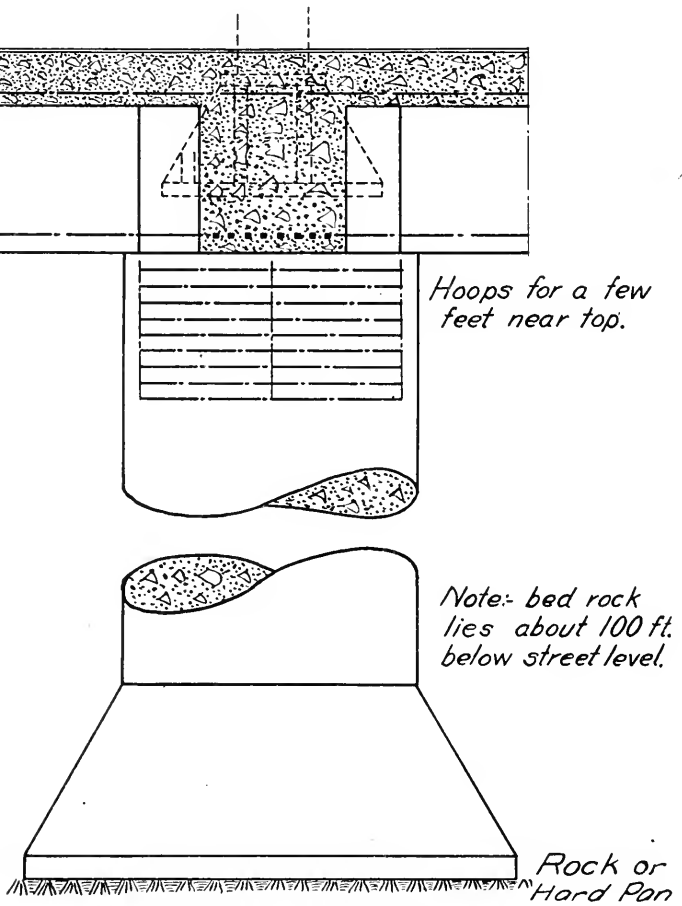
The piers for the columns on the property lines are often built with their centers on the lot line and are then used as party piers, supporting the columns of the two adjacent structures. In such cases separate grillages or bases are used for each of the two columns.

When the piers must be kept entirely within the property lines, as is very often the case, heavy cantilever girders are required to give a concentric bearing on the caisson. These girders may have two or more webs and must be properly fitted with stiffeners and often with reinforcing webs to take the shear. While the overhang of such girders is comparativly small, the loads for a sixteen story building are quite large, commonly from 1,000,000 to 1,500,000

pounds or more. The shear is, therefore, relatively large and it is often difficult to provide a sufficient number of rivets connecting the flange material to the web.

The load is properly distributed to the pier by grillages and steel slabs or by cast bases.

Grillages of either built or rolled beams are used where a cast base would become too large and unwieldy, and for distributing the load from the cantilever girders. One tier of beams for the girders and two tiers of beams for the columns are ordinarily suffi-



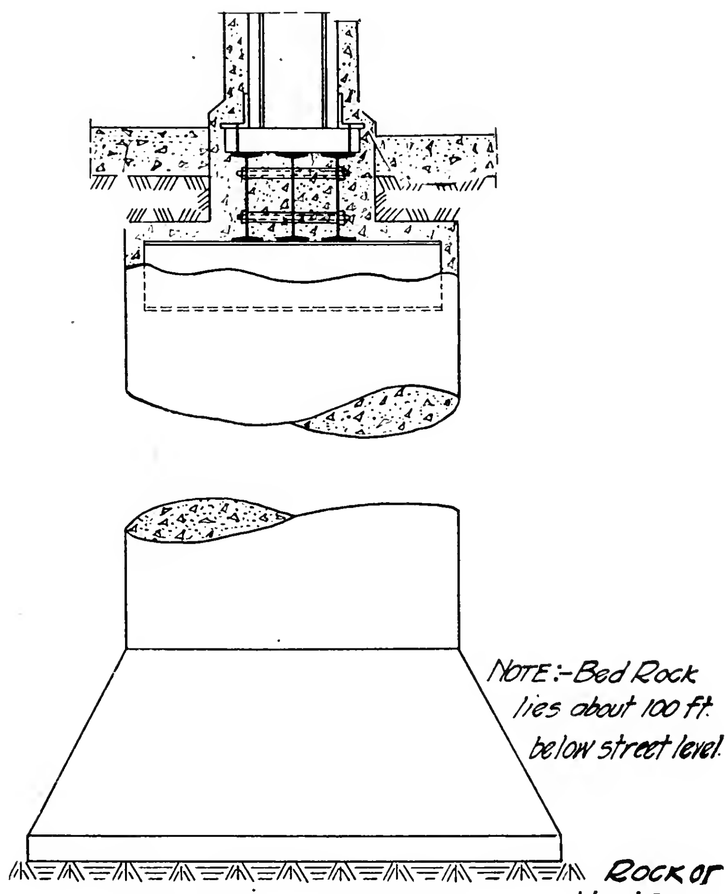
CAISSON WITH CAST BASE
Fig 1.

cient. The top tier of grillage beams should be properly held in position by gas pipe separators and bolts and properly encased in concrete.

Rolled beams with fitted stiffeners should be used only when it is impossible for lack of space to use enough I-beams of heavy webs to secure ample section for bearing. The webs should be heavy enough to offer resistance against buckling. It is quite difficult to obtain the best results in fitting stiffeners to rolled beams. The slope of the flange of rolled beams makes it difficult to provide

a good bearing for the stiffeners. Square grillages should be used where possible, thus making all grillage beams the same length, which reduces the number of erection marks and simplifies the work for both the erector and the fabricator.

Rolled steel slabs are often used and are efficient for distributing the column load to the cantilever girder or to the grillage beams. These slabs will vary in thicknesses from 2½ inches to 6 or 8 inches, depending upon the load and the area of distribution. These slabs are very efficient in distributing the load in a very small height and give a very satisfactory detail.



CAISSON WITH GRILLAGE.
Fig. 2.

Cast iron bases are often used for distributing the column loads into the masonry. For the heaviest column loads, cast steel bases are used. However, because of the absolute reliability of the slabs, accuracy in computing strength, ease of fabrication, etc., the slabs are recommended in place of the castings.

When cast bases or slabs are used the base plates of the columns may be omitted and the milled end of the column rest directly upon the cast base or slab.

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RETAINING WALLS.

It is common in the construction of the larger buildings in the loop district to construct three basements below the street level. In addition to the space so provided, further advantage is obtained by making connections to the tunnel system. This tunnel is used

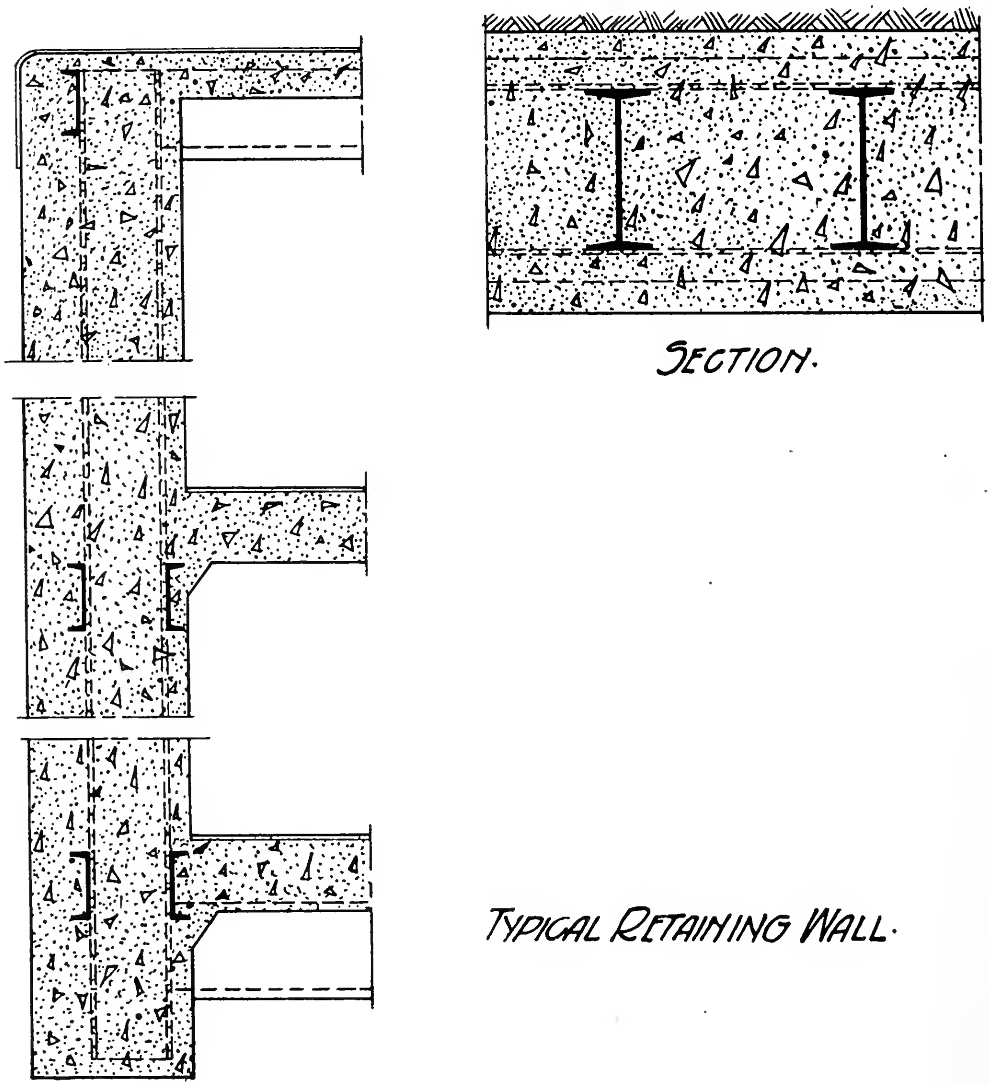
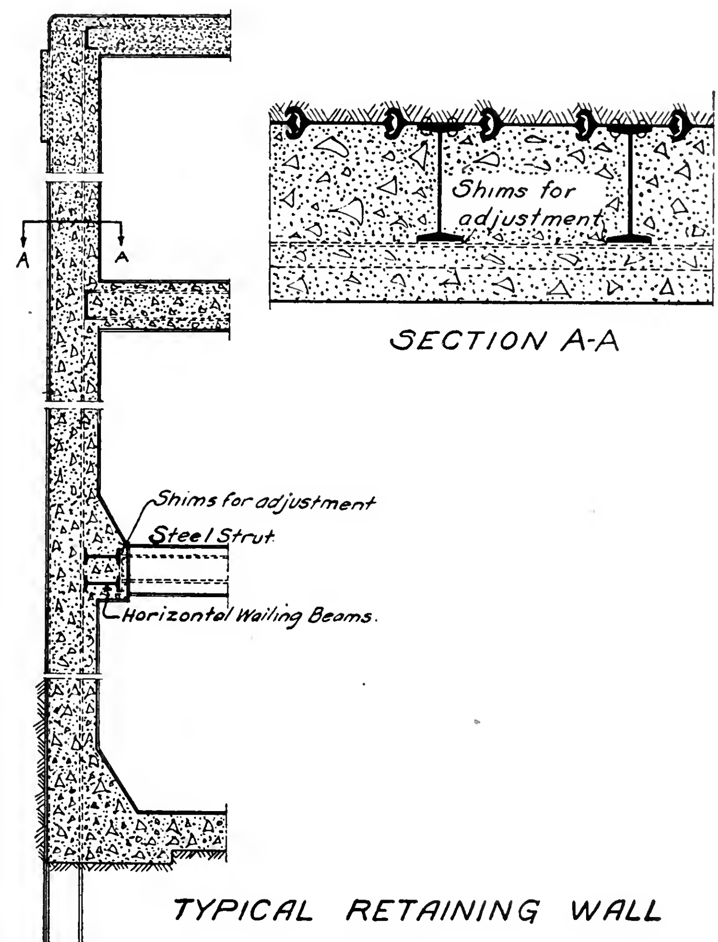


Fig. 3.

for the transportation of freight to and from the building, and also for the removal of the earth from the building site. The lowest basement floor is, therefore, placed at about the same elevation as this tunnel, which is about 40 to 45 feet below the street surface.

This construction makes necessary the use of rather high retaining walls. Such retaining walls may be built of reinforced

concrete, but are more generally some combination of structural shapes and concrete. These retaining walls are ordinarily designed as vertical slabs supported at the floor levels. At the floor levels the pressure is carried entirely across the building and balanced by earth pressure from the opposite side, or where such pressure does not exist, the floor construction is assumed to act as a horizontal beam, being supported at the two ends and receiving a distributed load. This is accomplished by the heavy concrete floor construction or by the steel struts placed between the columns.



TYPICAL RETAINING WALL

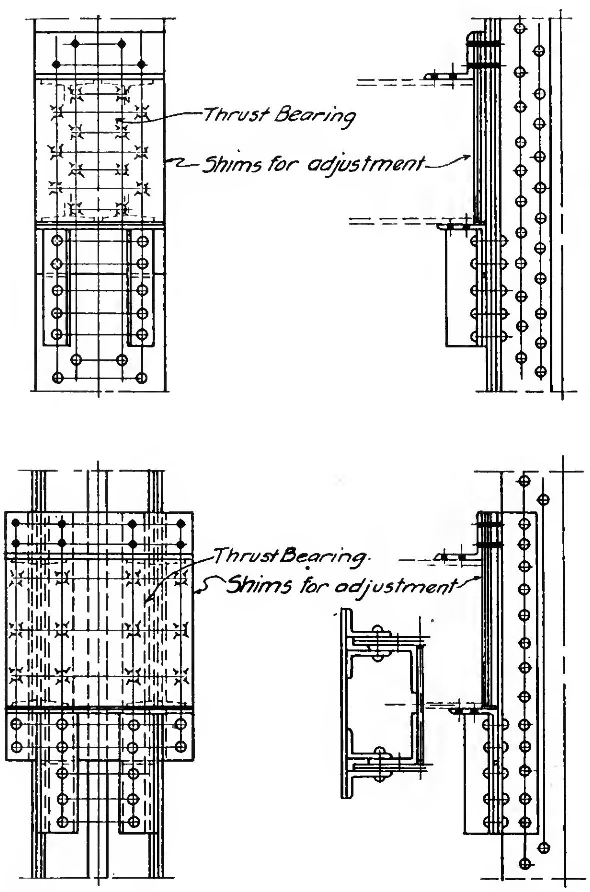
Fig. 4.

These struts require special details at the columns in order that the thrust may be properly transmitted and that adjustment may be made to fit the sheet piling. The thrust is usually taken care of by providing a proper bearing area on the column and milling the ends of the struts. The adjustment is provided by the use of shims between the milled end of the strut and the bearing area.

Two types of retaining walls as used by different designers are shown in Figs. 3 and 4, and typical strut connections to the columns are shown in Fig. 5.

In the construction of the type shown in Fig. 3, the excavation for the wall is first made. The temporary lagging to retain the earth is placed as the excavation proceeds. The beams are then placed in one or more lengths and are not finally braced until the basement floors are constructed. The beams are finally encased in concrete, which acts as the diaphragm between the beams, the entire bending being taken by the steel beams.

In the type shown in Fig. 4, the sheet piling and the connected beams are first driven. The sheet piling retains the earth and



TYPICAL CONNS. FOR BSMT. STRUTS TO COLS.
Fig. 5.

requires no temporary lagging. This piling will depart considerably from its original position during the driving, so that the measurements for the struts must be taken after the piling is driven. The concrete does not entirely encase the beams, so that the steel is but partially protected.

The writer prefers the type shown in Fig. 3, as this permits accurate alignment and permits the fabrication of all material without resorting to final field dimensions.

The sheet piling type shown in Fig. 4 will ordinarily drive very

irregular and will require the liberal use of shims in order that the various members may take their proper share of the loading. This type requires that the lengths of the struts be determined after the piling is driven and thus usually results in much delay and inconvenience to the fabricator and the erector.

The method of constructing the various basements is briefly as follows: The retaining walls are among the very first to be constructed. In that type having sheet piling, it is customary to require that this be driven before the basements are excavated. After the piers are built and the lower sections of the columns set, sufficient material is then excavated so that the first floor framing may be placed. This framing is then placed and riveted to the retaining wall and columns and the excavation then proceeds to the next lower floor. The framing of this lower floor is then placed and the retaining wall properly braced to this depth. The process is continued until the final basement floor is completed. The excavation is carried on simultaneously with the erection of the upper parts of the structure and the material is removed through the tunnel and does not interfere with the other building operations.

EXTRACTS FROM BUILDING ORDINANCE.

COLUMNS.

518. *Live load on walls, piers and columns.* The following table gives the proportion of live load to be taken in the design of walls, piers and columns:

FLOOR	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
17	85	per cent.															
16	80	85															
15	75	80	85														
14	70	75	80	85													
13	65	70	75	80	85												
12	60	65	70	75	80	85											
11	55	60	65	70	75	80	85										
10	50	55	60	65	70	75	80	85									
9	50	50	55	60	65	70	75	80	85								
8	50	50	50	55	60	65	70	75	80	85							
7	50	50	50	50	55	60	65	70	75	80	85						
6	50	50	50	50	50	55	60	65	70	75	80	85					
5	50	50	50	50	50	50	55	60	65	70	75	80	85				
4	50	50	50	50	50	50	50	55	60	65	70	75	80	85			
3	50	50	50	50	50	50	50	50	55	60	65	70	75	80	85		
2	50	50	50	50	50	50	50	50	50	55	60	65	70	75	80	85	
1	50	50	50	50	50	50	50	50	50	50	55	60	65	70	75	80	85

The full live load on roofs shall be taken.

(c) The proportion of the live load on walls, piers, and columns on buildings more than seventeen stories in height shall be taken in same ratio as the above table.

541. *Working stresses.* The allowable compression stresses per square inch shall be determined by the following formulæ:

Steel .... $16{,}000 - 70 \frac{L}{R}$, maximum 14,000

Wrought Iron .... $12{,}000 - 60 \dfrac{L}{R}$, maximum 10,000

Cast Iron .... $10{,}000 - 60 \dfrac{L}{R}$, maximum 10,000

In the above formulæ,

L equals length in inches,

R equals least radius of gyration in inches.

(d) For steel columns filled with, and encased in concrete extending at least three inches beyond the outer edge of the steel, where the steel is calculated to carry the entire live and dead load, the allowable stress, per square inch, shall be determined by the following formula:

$$18{,}000 - 70 \frac{L}{R}, \text{ maximum } 16{,}000.$$

(e) For steel columns filled with, but not encased in concrete, the steel shall be calculated to carry the entire live and dead load. In this case, the above formula may be used, but the allowable stress shall not exceed 14,000 pounds.

(f) Stresses due to eccentric loading shall be provided for in all compressive members.

(g) The length of rolled steel compressive members shall not exceed one hundred twenty times the least radius of gyration, but the limiting length of struts for wind bracing only, may be one hundred fifty times the least radius of gyration. The limiting length for cast iron columns shall be seventy times the least radius of gyration.

(h) Cast iron columns shall not be used in buildings of greater height than twice the least width, or in buildings over one hundred feet high.

542. Wherever the live and dead load stresses are of opposite character, only 70 per cent of the dead load stress shall be considered as effective in counteracting the live load stress.

(b) For stress produced by wind forces combined with those from live and dead load, the unit stress may be increased fifty per cent over those given above; but the section shall not be less than required if wind forces be neglected.

COLUMNS.

The two types of columns most extensively used in this city are the plate and angle and the plate and channel. Of these two types, the plate and angle column is the more common. Various other types, including forms having two or more webs, are also in use but not to such an extent as the two named.

A column with two or more separate webs is always objected to by all fabricating shops. Such a section cannot be moved progressively, through the shop, but must be successively moved back and forth through the assembling and riveting shops. Parts must be riveted before others are assembled, and these in turn riveted before still others are assembled, and so on. Such a column, thus involves a number of operations of riveting and assembling. Should a connection be erroneously riveted and this not observed until the column is complete, almost the entire column must be torn apart in order to correct the error. All web connections in

field must be made with through bolts. For these reasons the three web column should not be used unless these reasons be overbalanced by other considerations of design.

A plate and channel column is subject to some of the same objections, though to a lesser degree, and is, therefore, not as much in favor with the fabricators as the plate and angle type. This column, when designed according to the Chicago Building Ordinance, permits a higher working stress than the plate and angle type, and, therefore, effects a small economy of steel.

PLATE AND ANGLE TYPE.

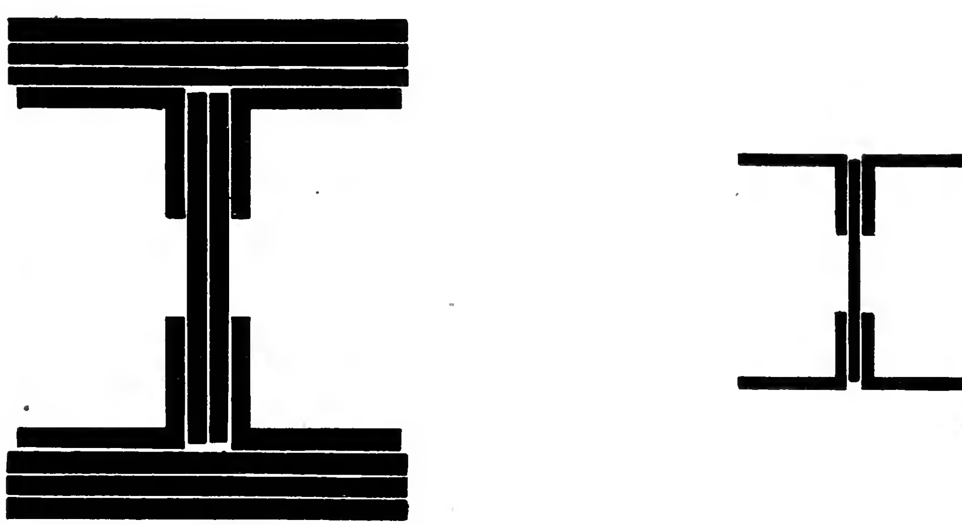


Fig. 6.

Consider a typical building in which the heights from floor to floor are 12 ft. 0 in. and where columns are to be designed according to the Chicago Building Ordinance. In order that the maximum allowable compressive stress may be available, the least radius of gyration of the column must be about 5. This value for a plate and angle column can be obtained for the larger sizes only, such as column with 20 in. cover plates, whereas in a plate and channel column, this value may be obtained with 16 in. covers. The following are approximate values only, but may be used as a basis of comparison of the two types:

PLATE AND ANGLE COLUMNS.

Covers.	Least Radius of Gyration.	Allowable Working Stress.
12 in.	3.0	12,800
14 in.	3.5	13,200
16 in.	4.0	13,500
18 in.	4.5	13,800
20 in.	5.0	14,000

PLATE AND CHANNEL COLUMNS.

Channel.	Covers.	Least Radius of Gyration.	Allowable Working Stress.
10 in.	12 in.	3.4	13,100
	14 in.	4.2	13,600
12 in.	14 in.	4.2	13,600
	16 in.	4.8	13,900
15 in.	16 in.	4.8	13,900
	18 in.	5.4	14,000
	20 in.	5.9	14,000

Comparing the working stresses of the two types, it will be noted that, for the same size cover, the plate and channel column permits a working stress about 350 lbs. per square inch higher than the corresponding plate and angle column. Or in percentage,

$$\frac{350}{13{,}000} = 2.7\%.$$

Therefore pure economy of steel will be in favor of the plate and channel type by approximately 3%.

In the preceding comparison, plate and angle columns with cover plates have been compared with plate and channel columns. This, it is thought, is a just basis for comparison, for in a 14 to 17 story building the majority of the columns will have cover plates. If plate and angle columns without covers be used in a comparison, the economy will, of course, be still more in favor of the plate and channel type.

The smaller radius of gyration of the plate and angle column about an axis parallel to its web makes this column not very efficient for bending at right angles to its web. However, in most cases, the column can be so arranged that it will be in its most efficient position for resisting bending, due to wind pressure.

A comparison of the larger radius of gyrations of the two types considered will show that they are about equal for comparable sizes. Hence it must be concluded that for bending at right angle to this axis, the two types are equally effective.

The plate and angle column has certain advantages over the plate and channel type: Various types of connections are made more easily. Field rivets may be driven in both the web and the flanges, thereby giving greater freedom in providing connections for easy erection. The fabrication is more simple and does not involve forward and backward movements in the shop. Errors are

more easily remedied and revisions more easily made, as same may be made without tearing the column apart. For these reasons this type of column is preferred by engineers and accounts for its extensive use.

The upper tiers of columns should always be designed without cover plates if possible by increasing the thickness or the width of the outstanding leg of the angles, thus simplifying the fabrication.

Columns must be investigated for at least two sets of conditions: First, dead and live load and bending produced by the eccentric application of these loads; second, dead and live load, wind direct load, and bending produced by eccentric loads and wind loads. The first condition must not produce a maximum stress in

PLATE AND CHANNEL TYPE.

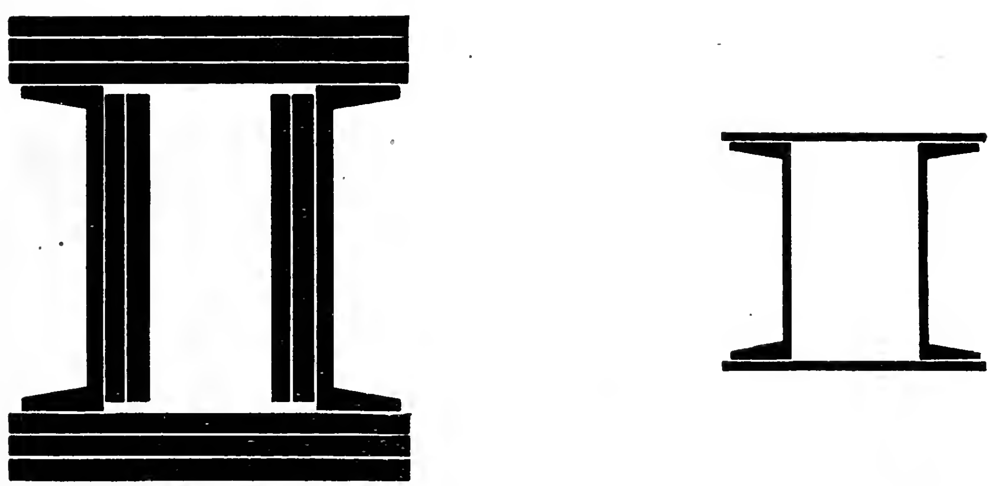


Fig. 7.

excess of that permitted by the ordinance, while in the second condition this allowable stress may be increased 50 per cent according to the ordinance.

Columns with very large wind bracing brackets and taking considerable wind bending should be investigated for ability to properly develop this bending. The stress due to bending must be transmitted from one flange to the other and this must be taken through the web. The rivets from the angles into the web must be able to transmit the increment of the bending stress. At each wind bracing bracket, the rivets in the web should be closely spaced for a distance at least equal to the length of the bracket.

October, 1916

The spacing or locations of columns will, in most cases, depend on conditions of the problem and will require study for each particular building. Pure economy of steel will require that columns be spaced about sixteen feet centers; but other factors will usually enter into and modify this spacing. These factors are due largely to architectural features, such as wall openings, partitions, space requirements, etc.

The problem will usually resolve itself into: With a given set of conditions, more or less rigid, to determine the most advantageous column locations. In this matter a re-study of the architectural feature by the architect, with desirable column locations in mind, will often result in quite a saving in structural cost. The architect, quite naturally, has his own features chiefly in mind and is apt to overlook important details which materially increase the cost of the

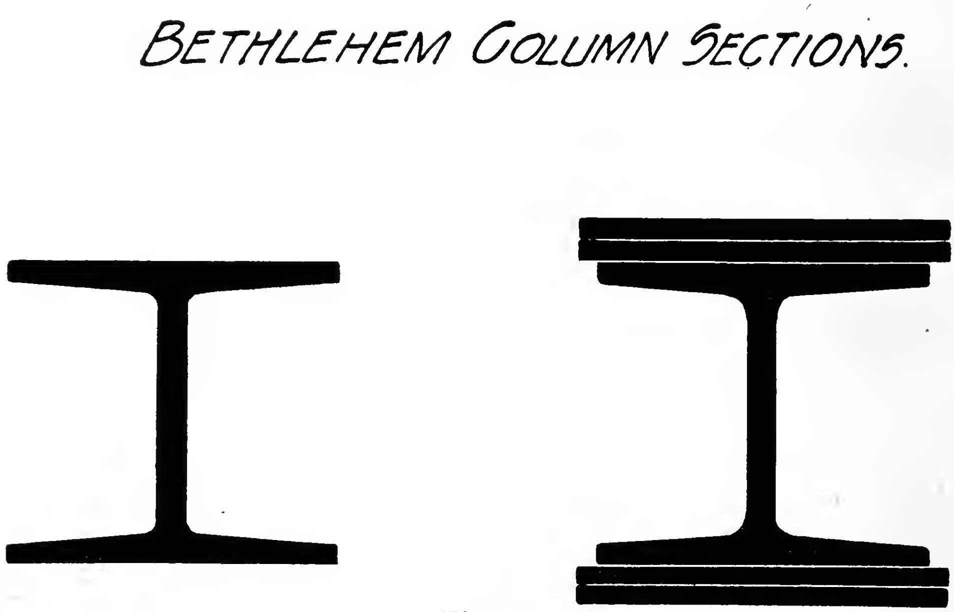


Fig. 8

structural frame. The designer, in this matter, acts in an advisory capacity and with the co-operation of the architect, determines the most suitable column locations.

In this matter but a few points need be mentioned, as these are recognized by all designers. Obviously, the spacing will be made as near to the economical as conditions will permit. Columns should be so located that the building will be divided into a series of panels, making as many equal and rectangular as possible. Duplications greatly reduce the cost of drawings and simplify fabrication and erection. Columns should be arranged, if possible, in continuous lines, as this will aid the rigidity of the structure and simplify erection and fabrication.

The general practice is to design columns in two-story lengths. The splices are generally located a little above the floor level. This

THREE CHANNEL TYPE.

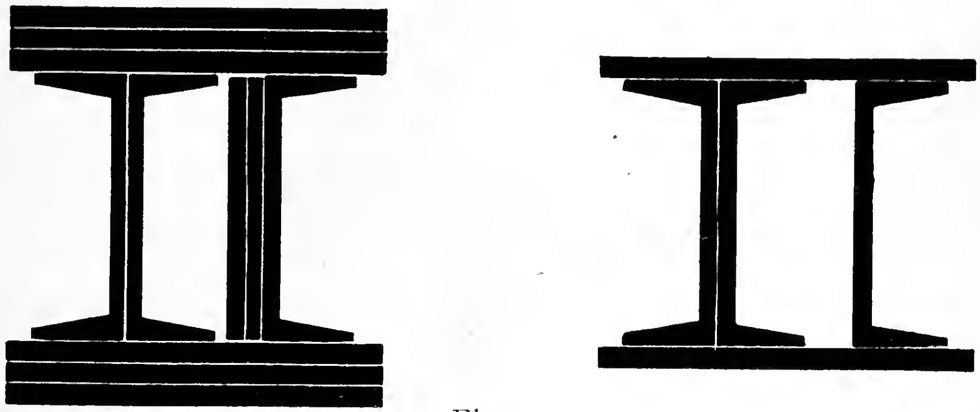


Fig. 9

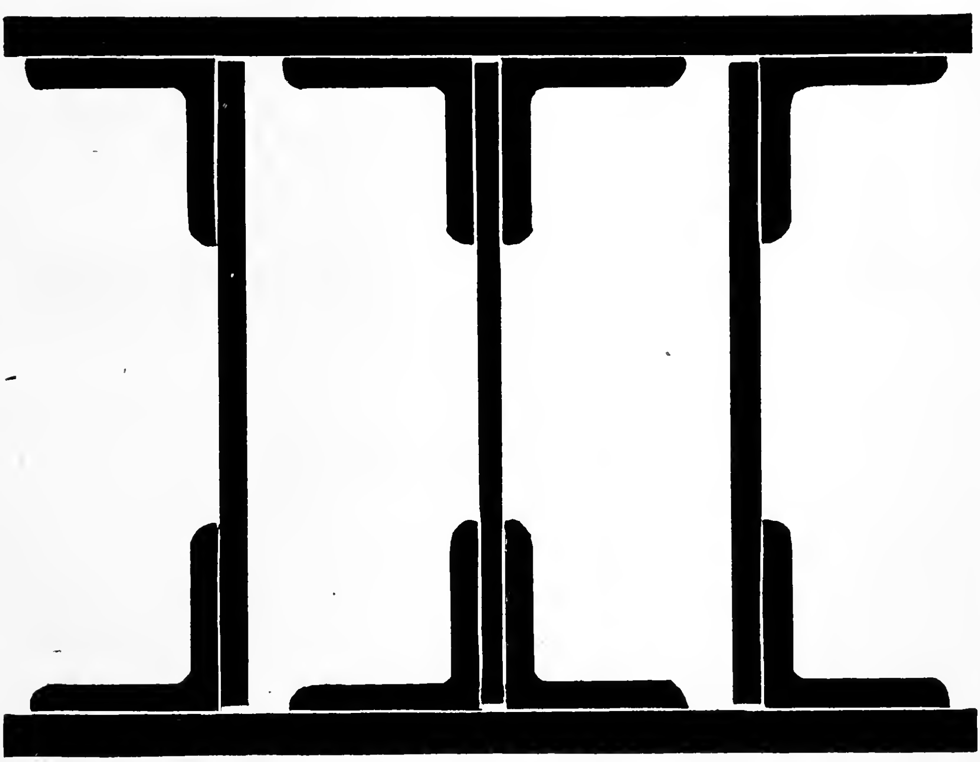


Fig. 10

has the advantage of splicing the column where it is most rigid and is also an advantage in erection.

Splices should not stagger at the different floors as this will be a great inconvenience to the erector and will make it practically impossible to erect or fabricate a building by tiers.

Special cases where wind bracing brackets are used will make the splice more desirable at some point above the top of brackets. In designing columns and wind bracing girders, the common assumption is that the point of contraflexure of the column is midway between floors, and this would indicate that the mid-point is the proper place to splice the column. But because of the direct loads

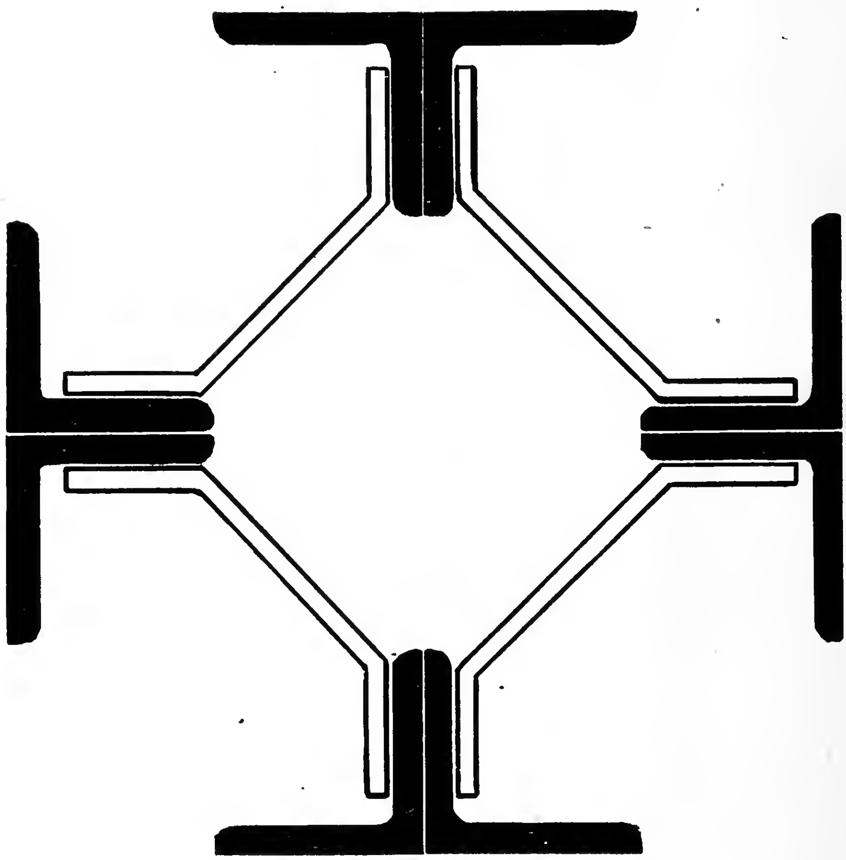


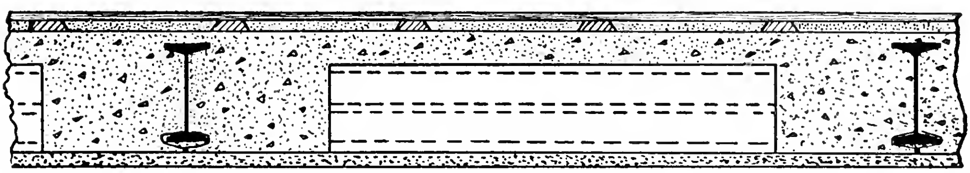
Fig. 11

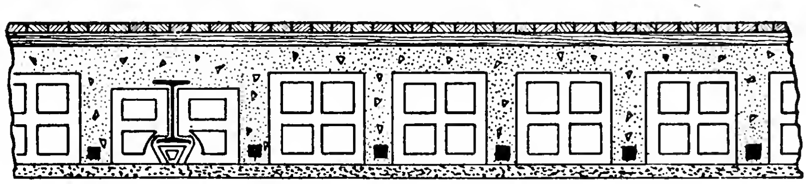
some bending will still exist at the middle point. Then the splice should be made at a point where the column is thoroughly braced. The general practice for wind bracing columns is to make the splice as near to the floor level as the wind bracing bracket will permit.

When columns take wind stresses, the splice must be investigated for ability to transmit the horizontal shear and the bending moment. This bending stress in the average case will seldom be large enough to overcome the direct load and put any part of the column in tension, though such a condition may arise.

Generally a column splice with cap angles is desirable; that is, splice plates are used on the flanges and angles on the webs. This type of splice facilitates erection. When the column section changes in width a cap plate is inserted between the abutting ends to distribute the bearing. A further advantage of this type of splice is that it eliminates considerable field reaming of the holes in the web splice plates and also reduces the number of field rivets.

Figure 6 shows a column of the plate and angle type. Because of its simplicity, ease of manufacture, and adaptability for connections it is preferred to the plate and channel type shown in Fig. 7.





COMBINATION TERRA COTTA & CONCRETE.

Fig 12.

Figure 8 shows sections of Bethlehem columns which have in many ways the same advantages as the plate and angle section.

In Fig. 9 a column section of the three channel type is shown. Because of the greater expense in manufacture and the difficulty of making the beam connections, this type should not be used except where unavoidable.

The three web type of column section is shown in Fig. 10. The objections to this type are the same as for the three channel type.

Gray column sections shown in Fig. 11 have been used on a number of the reinforced concrete buildings. Their advantage consists in securing a large radius of gyration with a minimum amount

of steel. Within the last few years this column has been superseded by the plate and angle column. The Gray columns are difficult to manufacture and for the heavier loads the section must be designed of large dimensions to secure clearances to drive the bent tie plate rivets.

EXTRACTS FROM BUILDING ORDINANCE.

The following extracts from the Chicago Building Ordinance are the more important bearing on floor construction:

FLOORS AND FLOOR CONSTRUCTION.

516. *Live loads in pounds per square foot.* Apartments, tenements, residences, school class-rooms, stables and carriage houses having an area less than 500 square feet............. 40
Office buildings, hotels, lodging or rooming houses, hospitals, jails, police stations, asylums 50
Corridors and assembly rooms of schools.................................. 75
Retail stores, warehouses, stables and carriage houses, with an area greater than 500 square feet, churches, dance halls, assembly halls, banquet halls, exhibition halls, theaters, buildings for manufacturing, department halls, grandstands, stairways, landings 100

(f) The live loads on stairways for buildings of all classes shall not be less than 100 pounds per square foot of treads and landings.

517. *Proportion of live loads.* Floors, joists and beams shall be designed for the full dead and live loads. Floor girders shall be designed for the full dead and not less than 85 per cent of the live load.

549. *Bending moments for concrete slabs reinforced in one direction.* W = load per lineal foot. L = span length in feet. When panels are approximately equal and equally loaded, bending moment at the center of the spans shall be taken as $\frac{W L^2}{12}$ for intermediate spans, and $\frac{W L^2}{10}$ for end spans.

(c) The moment over supports shall be taken not less than $\frac{W L^2}{18}$, and the sum of the moments over one support and at the center of span shall be taken not less than $\frac{W L^2}{6}$.

(e) *Span lengths to be used in computing moments.* For fully supported slabs, the free opening plus the depth; for continuous slabs, the distance between the centers of the supports.

567. *Working values for combination tile and concrete floors.* The provisions relating to reinforced concrete construction shall hold as far as applicable to this system. All tile shall be hard burned terra cotta tile of uniform quality, free from shrinkage cracks, with true beds and having an ultimate compressive strength of not less than 4,000 pounds per square inch of net area of surface tested.

The following stresses and values in pounds per square inch shall not be exceeded:

Extreme fibre stress (compressive) on hollow tile............ 500
Shearing stress on hollow tile................................ 200
Adhesion between tile and 1:2:4 concrete or 1:3 cement mortar.. 40
Ratio of modulus of elasticity of steel to that of tile with cement mortar joints 10

638. *Segmental and flat tile arches.* (a) Segmental arches shall have a rise of at least one inch for each foot of span of arch.

(b) The least thickness of a hollow tile or porous terra cotta segmental arch shall be one-half of an inch per foot of span, but no such arch shall be of a thickness less than five inches.

(c) Both flat and segmental arches shall be so constructed that the joints of the same radiate from a common center and there shall be a cross rib for every four inches, or fractional part thereof, in height in each tile block. The skew back of the arches shall be carefully fitted to the beams supporting them, and in addition to the cross ribs, there shall be additional diagonal reinforcing ribs in the skew back. Such arches, whether flat or curved, shall have their beds well filled with cement mortar, and the centers shall not be struck until the mortar has set.

(d) Burnt clay skew backs shall be molded in such a manner as to support the burnt clay covering on the under sides of beams or girders.

FLOORS AND FLOOR CONSTRUCTION.

The types of floor construction most commonly found in the modern buildings are as shown in Figs. 12 to 17, inclusive. These sketches are by no means intended to cover the entire range or even include all of the common types. They show, however, in the opinion of the writer, the more common.

The essential features to be considered in any floor construction are strength, stiffness, durability, fire-proofing qualities, light weight, small depth, and the cost. The construction of high buildings demands that the dead weight and the depth of the floor be reduced to a minimum, consistent with good construction and the cost. In recent years, various new types of floor construction have been placed before the designer and improvements have been made in the older types with the object of accomplishing these results. The forms used for concrete floors are also an important factor and have been subjected to much study and some reduction in the new types.

The partitions of office buildings are subject to continual rearrangement to suit different tenants, and the floor, therefore, should be designed to permit a partition to be placed in any position. This requirement is usually satisfied by assuming a certain weight (10 to 25 lbs. per square foot) for partitions and adding this to the dead load of the floor.

Flat ceilings are also desirable and this requires the use of suspended ceilings for some of the types of floor construction. Ample fire protection should be given the beam on both flanges.

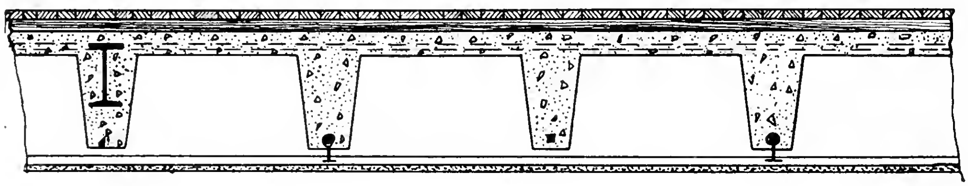
This paper does not attempt to discuss the relative advantages and disadvantages of various types of floor construction. The firms most interested have been quite successful in presenting the respective merits of their particular type and the designer must investigate these claims and make his choice accordingly.

The arrangement and the spacing of the floor beams are influenced by so many conditions, such as location of openings, the locations where comparatively deep beams are permitted, etc., etc., that it is impossible to suggest a particular set of rules to be followed.

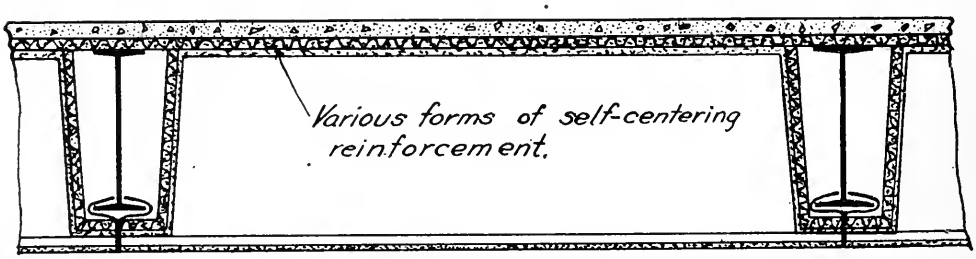
The columns having been located and as it is desirable in all

cases to transmit the floor loads as directly as possible to the columns, the main panels will be determined from this consideration, The economical span of the type of the floor construction will limit the size of the sub-panels. Thus, for terra cotta arches the usual span is from 5 feet to 6 feet, for reinforced concrete slabs, the span will probably be larger, but not to exceed 8 feet to 9 feet, while for the concrete joist construction no intermediate panels will be required, as this construction may safely be used for spans up to 26 feet or 28 feet.

For large stretches of floor surface the arrangement of the beams may be influenced by the desire to give continuity to the floor



CONCRETE JOIST TYPE.
FIG. 13.

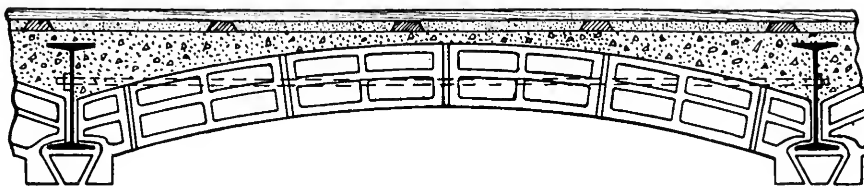


CONCRETE SLAB ON SELF-CENTERING
FIG. 14.

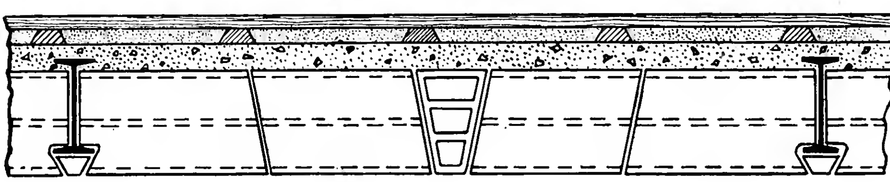
construction. Also, usually there will be a number of floor beams in the panel and only one girder, and as the clearance may limit the depth of the girder, it may be desirable to run the beams in the long direction and the girder in the short direction in order that the latter may not become too deep. Another factor which may determine the direction of the girder is the wind bracing, which may require that the deep girders run in the small direction of the building in order to obtain the advantage of the stiffness of the deep girder connections.

In all cases, however, it should be the aim of the designer to make as many panels equal and rectangular as the general plan will permit. This will give duplication in the structural steel, concrete forms, and terra cotta blocks.

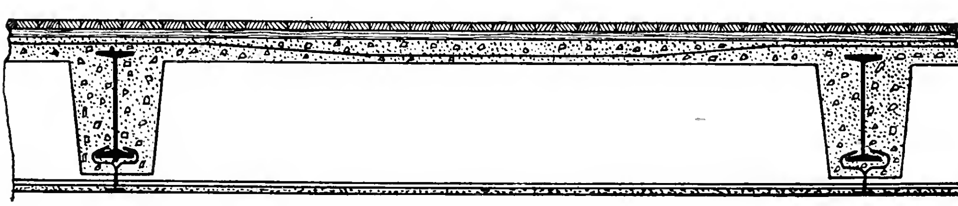
Beam to beam connections are made, in most cases, by simple



SEGMENTAL TERRA COTTA ARCH.
Fig. 15.



FLAT TILE ARCH.
Fig. 16.



REINFORCED CONCRETE SLAB.
Fig. 17

web connections. These may consist of one or two angles, or in skew connections of bent angles or plates. It will be necessary at times to make a connection by resting one beam on top of another, in which case it may be necessary to investigate the webs of these beams for buckling resistance. Beams framing into shallower ones

should be avoided, as this requires large cuts in order to clear the flanges of the shallow beam.

Unnecessary coping and blocking at the ends of the beams should be avoided and this may be done in many cases without injuring the construction in any way. For instance, very often the floor beams are not as deep as the girders into which they frame. By placing the beams at a slightly different elevation than the girder (1 in. to 1½ in.) connection may be made without any cutting. Holes in both the flanges and the web should be avoided where possible and only one size of hole should be used in any one beam. The cutting of beams and the punching of two sizes of holes in a beam, while of small importance in the design of the building, increases the cost of fabrication considerably and may many times be avoided by a little thoughtfulness in designing.

Beam to column connections are probably most satisfactorily made by using top and seat angles, with stiffener angles if required by the load. This type of connection for the usual sizes of rolled beams is capable of transmitting a larger moment than the web connection and is, therefore, more desirable for wind bracing.

In many cases the clearance lines will not permit the use of stiffener angles. In such cases simple web connections must be used. A satisfactory wind bracing connection may very often be made by the use of web connection angles with top and bottom seat angles.

When a shallow beam frames into a deep beam, this should be carried on a shelf angle and a side connection angle instead of the usual web connection. This connection is an advantage to the erector, as the shelf angle acts as an erection seat, thus facilitating the erection. This is especially noticeable when two small beams frame opposite each other. The smaller beams thus become plain punched beams without riveted connection angles and take a lower classification and a less unit cost.

EXTRACTS FROM BUILDING ORDINANCE.

PARTY WALLS.

519. *Thickness of Walls.* (n) The story height of buildings shall be the distance between structural floor systems or between such structural floor systems and structural roof systems and shall be as follows:

Where 12-inch walls are used, the story height shall not exceed 18 feet.
Where 16-inch walls are used, the story height shall not exceed 24 feet.
Where 20-inch walls are used, the story height shall not exceed 30 feet.

(o) Where the story height is greater than thirty feet, the walls shall not be of less thickness than the following: The upper fifteen feet shall be not less than sixteen inches in thickness, and the walls shall be increased four inches in thickness at each interval of fifteen feet or fractional part thereof of height.

(p) Curtain walls in skeleton construction buildings may be of hollow clay tile of the same thickness as herein required for brick walls.

521. *Walls of Altered Buildings—Increasing Thickness of.* If the walls

of a building are not of sufficient thickness to comply with the requirements of this chapter for an enlarged or modified building, then the thickness of the existing walls shall be increased by building alongside of them a new wall, which shall not, however, be less in any part thereof than twelve inches for at least every forty feet in the height of such wall. Such new wall shall be laid in Portland cement mortar and shall be anchored to the old wall, but bonding with brick or masonry will not be considered as complying with this chapter; and if an increase in the height of the building is contemplated, the wall from the top of the old wall shall be built jointly upon the new and old walls. If solid masonry buttresses are introduced in connection with such thickening and strengthening of existing walls, the intervening walls may be reduced to eight inches in thickness, provided such buttresses are sufficient in number and in area to make the resultant structure of equal strength with the solid wall already specified. Provided, however, that steel or iron columns or beams may be used instead of such new wall, such columns or beams to be bolted or bonded to the existing wall in a manner satisfactory to and approved by the Commissioner of Buildings.

522. *Walls—Party.* The provisions of the preceding section shall also apply to all cases where existing party walls are to be joined to for the erection of new buildings. But in the case of party walls, which at the time of their erection were built in accordance with the terms of the city ordinances then in force, such walls, if sound and in good condition, may be used without increase of thickness for any building not higher than and of the same class as the building for which the original wall was built.

PARTY WALLS.

Self-supporting party walls resting on the upper soil have been in quite common use in Chicago. Such walls are often as thick as 28 or 32 inches at the base. Their use has effected quite a saving of space and cost, and for this reason they have been used in many of the buildings in the loop district. The existence of a party wall on the lot line when a steel skeleton frame is to be constructed; calls for some special consideration and features of design. The party wall must, in general, be preserved for the adjoining structure.

The party wall sets on the property line and is often found to be as much as 5 or 6 inches out of plumb. It often becomes necessary, therefore, to cut vertical and horizontal channels into these walls in order that the columns and the spandrel girders may be placed in their proper positions. The spandrel girders may be located as far inside the new structure as the conditions will permit, and may in addition be made of such shapes as to interfere as little as possible with the wall.

The erection and the riveting of the various members adjoining a party wall should be given careful thought by the designer. The field connections should be so designed that the girders can be swung into position from the inside of the building. The field riveting should be looked into. Very often it will be impossible to drive field rivets and tight-fitting bolts must then be used.

The soil conditions are often so much disturbed by the construction of the piers and by the excavation of the basement that it becomes necessary to provide new supports for the party wall. The common method is to support such a wall entirely at its base. The

spandrel girders are usually so designed that they carry very little, if any, of the party wall.

The girder which supports the old wall is usually of steel and may rest directly on the grillage or base, may be supported by an independent column, or may be connected to the building column.

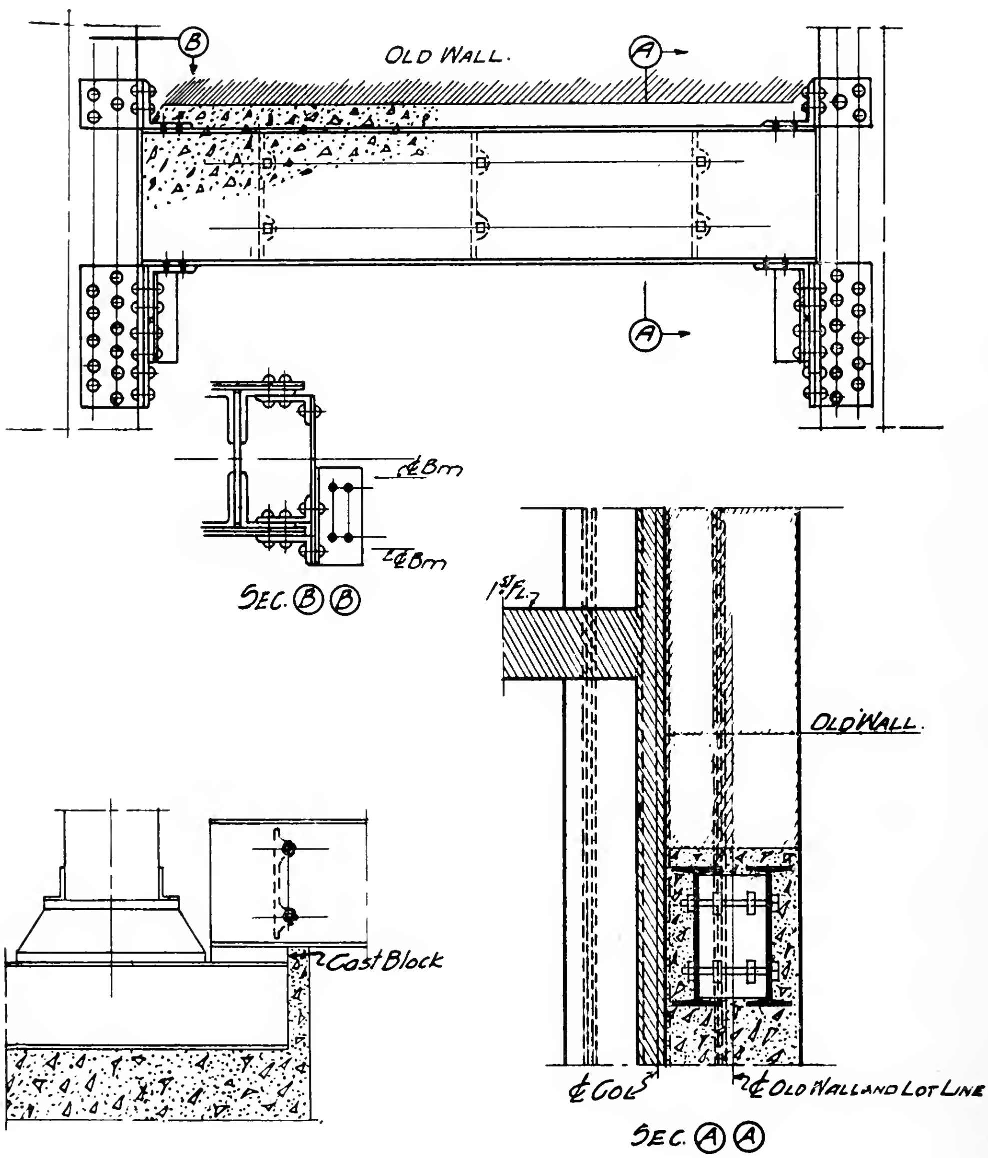


Fig. 18

The loads upon such girders are usually quite large and are generally some distance from the center of the building column. When these girders are connected to the building column, it is common to build this column eccentric in order to avoid the large bending stresses which would otherwise occur.

Figure 18 shows a typical girder supporting a party wall.

EXTRACTS FROM BUILDING ORDINANCE.

WIND BRACING.

516. All buildings shall be designed to resist a horizontal wind pressure of 20 pounds per square foot for every square foot of exposed surface. In no case shall the overturning moment, due to wind pressure, exceed seventy-five per cent of the moment of stability of the building due to dead load only.

542. For stress produced by wind forces combined with those from the live and dead load, the unit stress may be increased fifty per cent over those given by the ordinance; but the section shall not be less than required if wind forces be neglected.

541. (g) Limiting length of struts for wind bracing only, may be one hundred fifty times the least radius of gyration.

592a. All structures whose height exceeds twice their least dimensions at their base shall be so designed as to safely resist a wind pressure of 30 pounds per square foot of surface exposed to the action of the wind. (This wind pressure to be used on all structures other than buildings.)

WIND BRACING.

The subjects of wind bracing and wind pressure have received considerable attention in the last few years. A number of articles on these subjects have appeared in the engineering journals and, quite recently, the members of this Society have listened to the reading of two excellent papers on the wind bracing of office buildings.

Before entering into a discussion of wind bracing, the writer wishes to express the belief that our buildings in Chicago are generally designed with heavier bracing than is necessary. Of course, the requirements of the Chicago building laws must be complied with but the result is, generally, in trying to follow the Chicago laws that the provisions made for resistance to wind forces exceed the requirements of the law and are "extra" conservative. The New York laws do not impose the restrictions on engineers for wind bracing designs that the Chicago laws do. In New York the upper eight stories are exempt from bracing, permanent adjacent buildings are taken advantage of as a shield to wind and court shafts may be of smaller dimensions than those specified in the Chicago laws. Of course the effect of these New York ordinances is to materially decrease the wind bracing for the New York buildings.

The object of this paper is to treat of the details of wind bracing, or more specifically, of the connections of the wind bracing girders to the columns. A few general considerations, however, will be very briefly touched upon in order to properly lead up to the details.

The interior partitions, the floor construction and the exterior walls, all contribute to the rigidity of the building, though to an indeterminate extent.

The interior partitions of the modern office building are usually of a very light construction, and when of such construction can aid but very little in resisting wind pressure. It is, therefore, customary to neglect the stiffening effect of the partitions in such classes of buildings.

The floor construction, especially when this is some form of the reinforced concrete types, adds some rigidity to the structural frame. In the typical office building, however, the floors are made as shallow as possible. They can, therefore, aid but very little in giving stiffness in a vertical plane and are, therefore, customarily neglected.

The exterior walls are usually relied upon to carry a certain amount of wind pressure. This is quite commonly permitted in building codes by specifying a less intensity of wind pressure for the finished structure than for the exposed steel frame; also, by permitting buildings to be built to certain heights without any provision for wind pressure in the structural frame. Various building ordinances will permit a height of from two to three times the least horizontal dimension before requiring wind pressure to be considered.

The type of construction of floors and walls is an important one in determining the amount of wind bracing necessary; for instance, a brick wall, with few window openings requires less bracing.

Whatever amount of wind pressure is considered as being taken care of by the partitions, floors, and exterior walls, will generally be done by reducing the intensity of wind pressure for which the structural frame is designed. In the following, the wind will, therefore, be considered as being resisted entirely by the steel frame, allowances, however, should be made for such construction of floors and walls, which will add to the wind resistance.

In resisting wind pressure, the building acts as a cantilever beam and is held in position by forces acting at its base. While in ordinary cases there is but little danger of the building overturning, there is, however, quite a tendency for the building to rack, and this must be provided against by the proper design of the joints.

The structure is divided into a number of vertical bents and these bents are assumed to carry the wind loads to the foundation. These bents receive their loads from the floors, which act as horizontal beams.

Usually the floor construction is amply strong for such beam action and requires no special consideration. In extreme cases, as where the vertical bents must be offset to avoid interference with architectural features, the floor construction may require special reinforcement in order to take care of this beam action.

The vertical bents may be treated as trusses or the connections of the beams to the columns may be made of such strengths that the bents will act as portal frames or a series of portal frames.

To introduce diagonal members to take the shear and thus form a truss of the vertical bent is the simpler method. In this case the columns and beams take only direct stresses. This method of treatment, however, usually interferes with the openings and other architectural features and its use is, therefore, limited to blind walls or partitions.

The portal method adapts itself more readily to most cases.

The end connections may be adjusted so as not to interfere with clearances, openings and architectural features. This method, however, produces bending stresses in the columns and beams and requires care in the design of the end connections. It is concerning these connections that the writer intends to confine his attention in the succeeding few pages.

The methods used in the design of wind bracing without diagonals are quite generally known or may readily be referred to. Four approximate methods are in quite common use. Three of these, designated methods I, II and III by the author are described by Mr. R. Fleming in the Engineering News, March 13, 1913. The fourth method is described by Prof. A. C. Wilson in the Engineering Record, Vol. 58, p. 272, and corresponds to that mentioned as a special case of method II in the above article.

More exact methods, based upon the elastic distortions of the members comprising a bent or based upon the theory of least work, have at various times been proposed. Such methods will, of course, give more nearly the actual resulting stresses, but the amount of labor involved in these analyses is so great that they have been but little used.

Recently, Messrs. W. M. Wilson and G. A. Maney have offered a method in which the amount of labor has been materially lessened. This method is described in the University of Illinois Experiment Station's Bulletin No. 80 (Vol. 11, No. 40 dated June 7, 1915).

It is quite obvious that the total bending to be provided for at any floor level depends solely upon the height of the structure above that floor and upon the intensity of wind pressure. Any method of analysis must provide for this total bending at any one floor. The distribution of this bending among the columns and beams constituting a bent will, however, vary accordingly as one or another method of analysis is used.

Regarding the vertical bent in detail, we have in any method of analysis and in the most general case, at each joint a condition as shown in Fig. 19.

P1 and P2 are proportionate, respectively, to the total wind thrust above and below a given floor level. The difference between P2 and P1 is the horizontal increment received by the joint at the floor level. This increment must be taken as a direct stress by the connecting beam. The moment produced by P1 and P2 must be balanced by an equal counter moment produced by S1 and S2, which act as shears in the beams. In general, S2 and S1 will not have the same value and their difference must be taken by the column. This difference between S1 and S2 constitutes the increment of direct stress upon the column.

Regarding next the connection of the beam to the column. It is evident that this connection must transmit the following moment and forces: first, a moment equal to Sa, where a is the distance from the point of contraflexure of the beam to the column connec-

tion; second, vertical shear due to dead and live loads and the vertical wind shear (S) in the beam; third, horizontal thrust proportionate to the wind increment at the floor.

There is, also, a direct stress, of tension or compression, on this connection when the wind is acting at right angles to this bent, caused by the beam action of the floor. Connections designed for the forces shown in Fig. 19 will usually be amply strong to transmit this direct stress, though cases may arise when this will not be true. This discussion will be confined to the consideration of the connection, using forces shown in Fig. 19.

For small moments, rolled beams with properly developed end connections may be used as wind bracing girders. This method will prove most economical where same can be used.

As moments become larger, built up plate girders must be used. In many cases the end connections may still be sufficiently developed without the use of gusset plates, and this method will prove next in the order of economy.

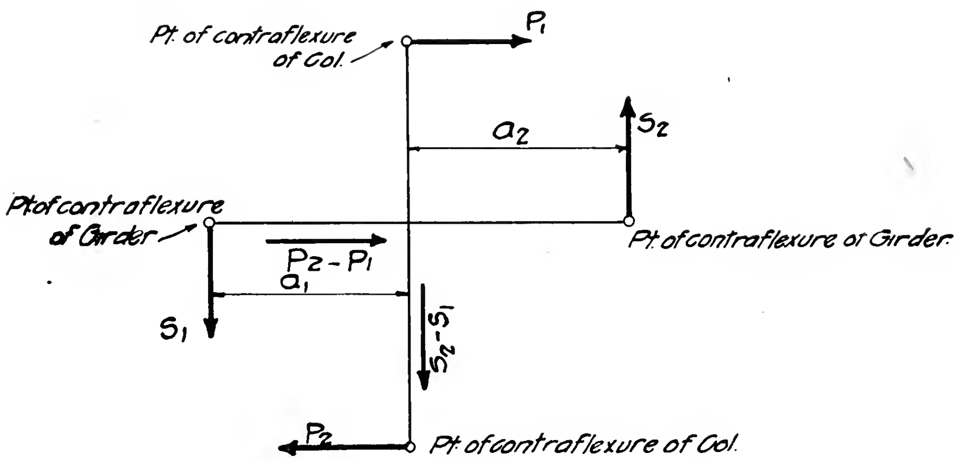


Fig. 19

For still larger moments, it will be necessary to use large gusset plates at the ends of the girders and to make a web splice. In severe cases economy may result in the use of knee braces.

It is often necessary in end connections and in gusset plates to transmit the stress from the beam or girder through connection angles and then into the column. Care should be taken in such cases to make the connection angles amply strong so that the full computed value of the rivets may be available.

The thickness of the connection angles is a matter that is sometimes not looked into by the designer. Designs for wind bracing girders showing three-eighths inch connection angles with a gauge in the outstanding leg of three or four inches, have been called to the attention of the writer. It is evident from a consideration of the nature of the stresses in these angles that but a small part of the value of the rivets is actually available in transmitting the wind

moment. It is also true that a thin connection angle will so distort as to vitiate results based upon the assumption of perfect rigidity of the joints, which is the assumption upon which all exact methods of analyses are based.

The following discussion will attempt to show the nature of the stresses existing in the connection angles and will propose a method for determining the required thicknesses. This method will, of necessity, be but incomplete as it is based upon assumptions which are but approximate and have not been verified by actual tests. The results, however, agree fairly with the values used in the most of the designs.

SIDE CONNECTION ANGLES.

Figure 20 shows the equilibrium conditions of two end connection angles and Fig. 21 shows in more detail the equilibrium conditions of one of these angles.

Figure 21 shows the general form of the elastic curve. In the

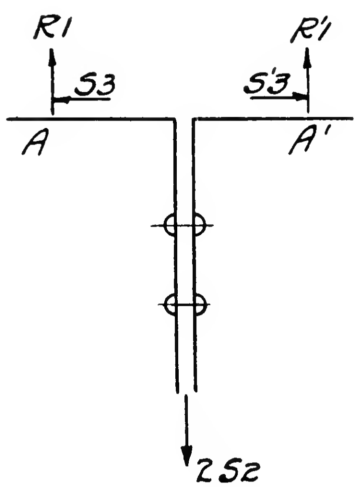


Fig. 20

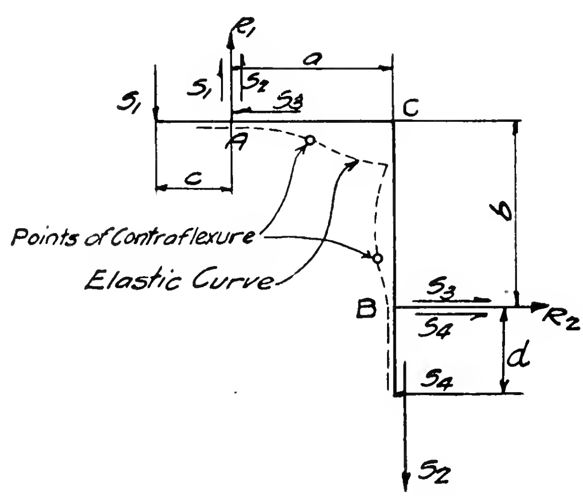


Fig. 21

analysis, a full degree of fixedness has been assumed at both legs. It is quite probable this can never be attained and that the true condition will be somewhere between full fixedness and no fixedness.

The section through the rivets is of less strength than the remaining portion of angle on account of the rivet hole, though this is partly compensated by the fact that the rivet head probably aids the section. The fillet at the root of the angle makes this section stronger than the rest of the angle. Some error is, therefore, introduced in assuming the moment of inertia of the angle constant throughout its length. Considering, however, the other indeterminations connected with wind bracing, it appears that a closer degree of refinement is not warranted.

In giving the final effective value of the rivets, the effect of the shifting of the point of contraflexure has been considered. These values have been somewhat modified in the direction of the values for zero fixedness at the sections through the rivets.

Referring to Figs. 20 and 21, S_2 is the effective force of one rivet that may be used in developing the resisting moment. The two angles are connected at B and constitute a beam supported at A and A′ and carrying a single center concentration $2S_2$. The force S_3 exists as an internal stress in this beam and is transmitted from one angle to the other through the rivet at B. From the consideration of the equilibrium of one angle, it is evident that this force must be balanced by an equal force applied to the rivet at A and A′. The fixing forces S_1 and S_4 are statically indeterminate, being dependent

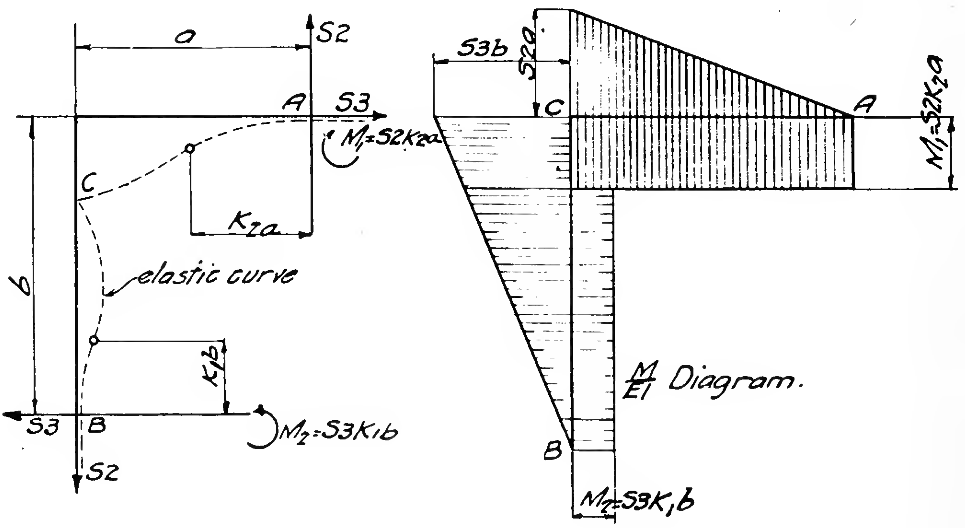


Fig. 22. Fig. 23.

upon the moments existing at A and B, and upon the distances c and d.

Referring to Figs. 22 and 23. Assume E and I, the modulus of elasticity and the moment of inertia of the angle respectively, constant for the entire section of the angle. Let S_2 be known; we have then three unknowns, M_1, M_2 and S_3.

Statics will furnish one equation and the other two may be obtained from a consideration of the elastic curve.

From statics, moment about B = O.

$$M_2 + S_2a - S_3b - M_1 = O \qquad \text{(1)}$$

The deflection of C with respect to the tangent at B is assumed equal to zero; therefore, the moment area of the moment diagram from C to B about C is equal to Zero.

$$S_3b \cdot \frac{b}{2} \cdot \frac{b}{3} - S_3K_1b \cdot b \cdot \frac{b}{2} = O$$

Solving, $K_1 = \frac{1}{3}$ ....(2)

The total angular change of the tangent at A with respect to the tangent at B is assumed equal to zero; or, the area of the moment diagram from A to B is equal to zero.

$$S_2a \cdot \frac{a}{2} - S_2K_2a \cdot a + S_3b \cdot \frac{b}{2} - S_3K_1b \cdot b = O$$

Substituting for K_1,

$$\frac{S_2a^2}{2} - S_2K_2a^2 + \frac{S_3b^2}{6} = O \qquad (3)$$

Substituting for M_1 and M_2 in (1),
$S_3K_1b + S_2a - S_3b - S_2K_2a = O$
Replacing K_1 by its value,

$$\frac{2}{3}S_3b - S_2a + S_2K_2a = O \qquad (1')$$

Eliminating S_3 from equations 3 and $1'$

$$-\frac{4S_3b^2}{6} = 2S_2a^2 - 4S_2K_2a^2$$

$$\frac{4S_3b^2}{6} = S_2ab - S_2K_2ab$$

$$S_2a\ (2a + b) - S_2K_2a\ (4a + b) = O$$

$$K_2 = \frac{2a + b}{4a + b} \qquad (4)$$

From $(1')$, $\frac{2}{3}S_3b = S_2a\frac{4a + b - 2a - b}{4a + b}$

$$S_3 = \frac{3S_2a^2}{b\ (4a + b)} \qquad (5)$$

Limiting values of K_2.

When $a = \frac{1}{4}b$ $\qquad K_2 = .75$
$a = \frac{1}{2}b$ $\qquad K_2 = .67$

$a = 1b \qquad K_2 = .60$
$a = 2b \qquad K_2 = .55$
$a = 4b \qquad K_2 = .53$

Considering that $a = \frac{1}{4}b$ is an extreme case not often met with and that a is equal to or greater than b in the common cases of practice, it appears reasonable and sufficiently accurate to use a value of .6 for K_2. This is also desirable in order to simplify results.

Values of S^2.—Referring to Fig. 24, the edge distance on the outstanding leg will, in general, be not less than $1\frac{1}{2}$ inches. Assuming a triangular distribution of the fixing forces, c becomes equal to unity and we have,

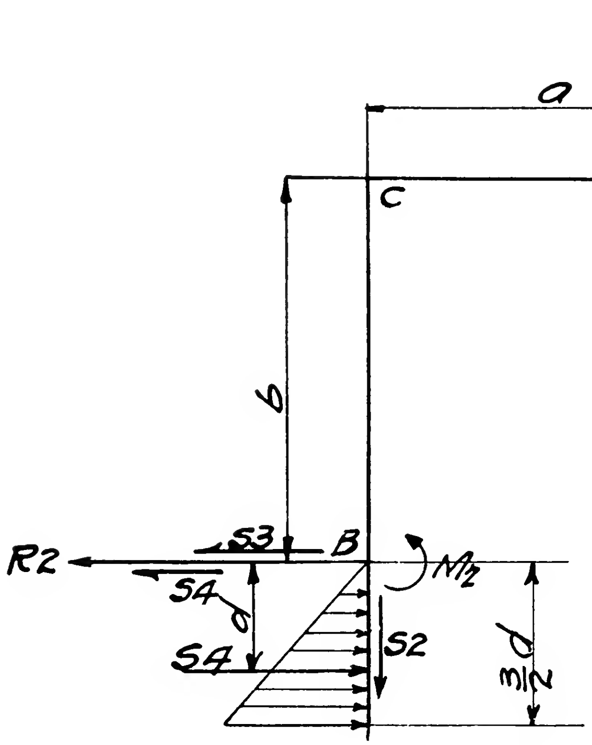


Fig. 24

$$M_1 = S_1 = .6\ S_2 a$$

$$R_1 = S_1 + S_2 = S_2\ (1 + .6a)$$

$$S_2 = \frac{R_1}{1 + .6a}$$

Figure 25 is a plot of the values of $\dfrac{S_2}{R_1}$ for various values of a.

Figure 26 is a plot of the values of M_1 assuming a full degree of fixedness at the rivet lines.

Values of S_3

$$S_3 = \frac{3\,S_2 a^2}{b(4a+b)} = \frac{3\,a^2}{b(4a+b)} \cdot \frac{R}{1+.6a}$$

For $b = 1\frac{1}{2}$ inches, and $a = 6$ inches (extreme values)

$$S_3 = R\,\frac{3 \times 36}{1.5 \times 25.5 \times 4.6} = .62R.$$

For $b = 2\frac{1}{2}$ inches and $a = 2\frac{1}{2}$ inches (common values)

$$S_3 = R\,\frac{3 \times 6.25}{12.5 \times 2.5 + 2.5} = .24R.$$

A horizontal shear from .2R to .5R acting upon the rivet at A will probably cover the more common cases.

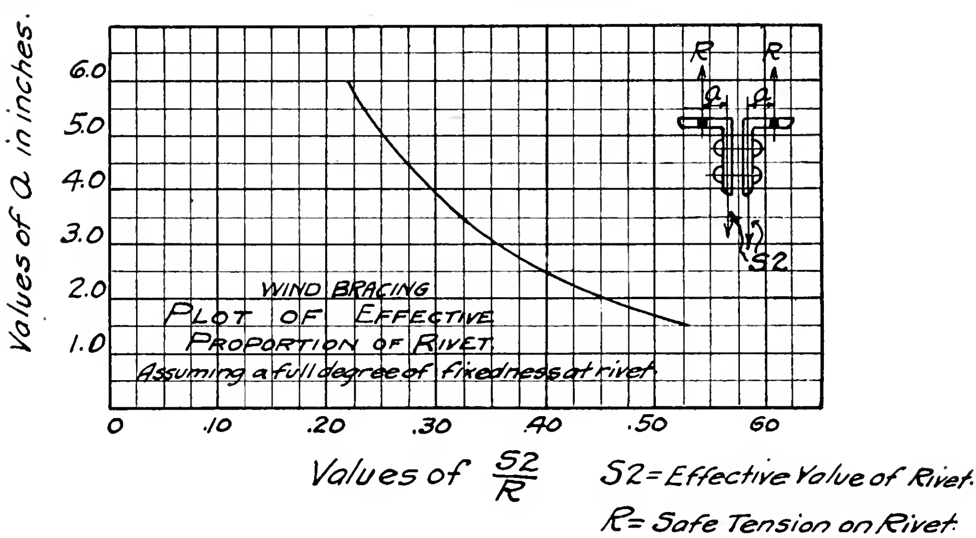


Fig. 25.

Values of S4. Assuming conditions as for S_1.
$S4 = M_2$, extreme case $S_4 = .31R$
Total tension on the rivet at B.
Extreme value, $R_2 = (.31 + .62)\ R = .93R$.
For common values of a and b, $R_2 = R\ (.20 + .24) = .44\ R$.
These values show that the tension on the rivet at B will approach, for extreme cases, the tension on the rivet at A and that more commonly it may be expected to be about one-half of this value.

Values of M_2

$$M_2 = S_3 K_1 b = \frac{S_3 b}{3} = \frac{S_2 a^2}{4a+b} = \frac{R}{(1+.6a)} \cdot \frac{a^2}{(4a+b)}$$

For $a = 6''$, $b = 1.5''$

$$M_2 = \frac{36R}{25.5 \times 4.6} = .31R$$

For $a = 2\frac{1}{2}''$, $b = 2\frac{1}{2}''$,

$$M_2 = \frac{6.25\ R}{12.5 \times 2.5} = .2R$$

Values of M_1. For most favorable case, $a = 1.5$, $b = 1.5$
$M_1 = S_2K_2a = .47R.$

The values of M_1 will at all times be larger than either M_2 or

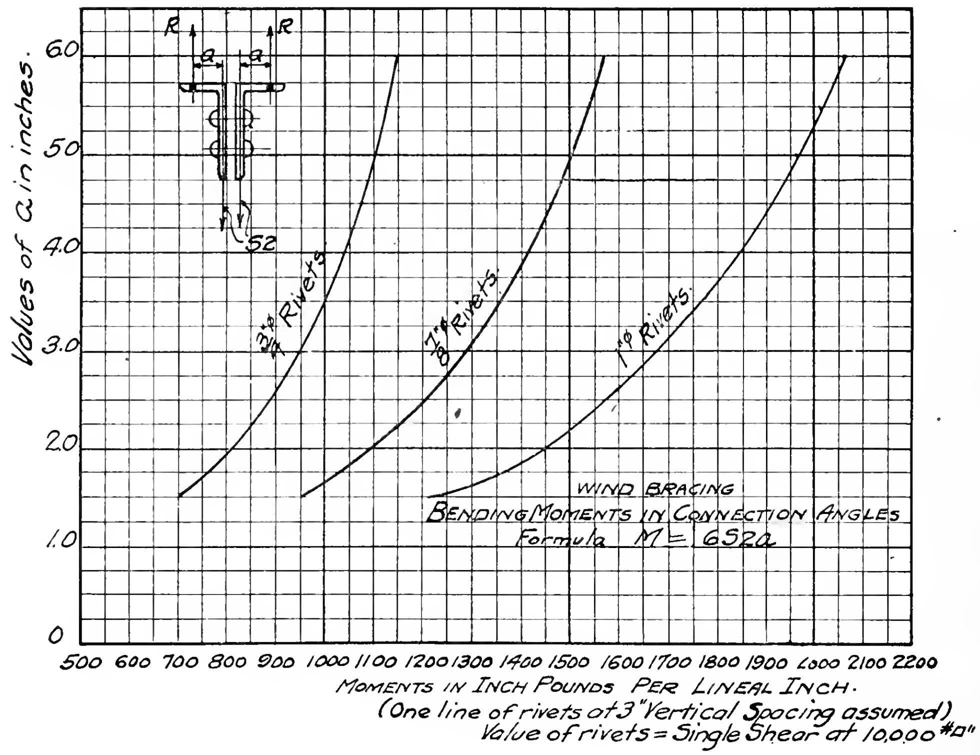


Fig. 26

the moment at the heel of the angle. This moment, M_1, may, therefore, be conveniently chosen as governing the thickness of the connection angle.

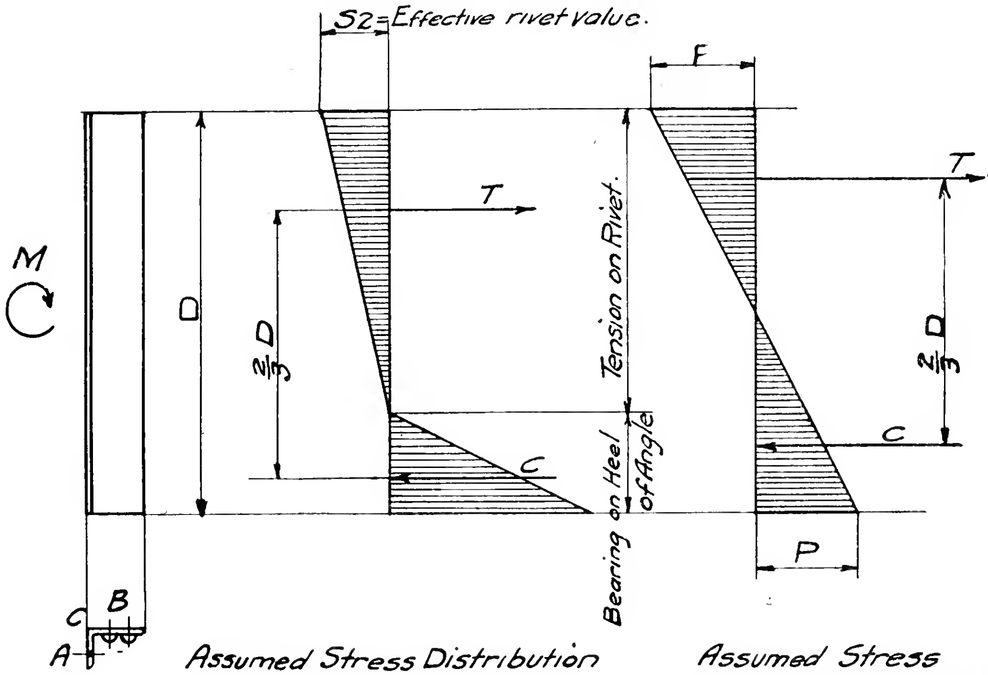
Consideration of the probable action of end connection angles. Figures 27, 28 and 29.

These two angles may be looked upon as constituting a vertical beam. The load is received from the column by bearing on the heel of the angles and by the tension on the rivets in the outstanding legs. This load is then delivered to the gusset plate or girder by the rivets in the other legs. If the angles be made stiff in the direction of the girder so that they are able to take some bending

in this direction, they then may be considered as performing the additional function of redistributing the stresses in the rivets.

It is purely conjectural to what extent this redistribution may take place. We have made a rather favorable assumption here in order that larger effective values of the rivets may become available. The tension in the rivets in the outstanding leg and the bearing on the heel of the angle have been assumed to be distributed as shown in Fig. 27. The distribution of stress in the rivets in the leg connecting the angle to the gusset plate is shown in Fig. 28.

These distributions are, of course, very approximate only, as it appears that, if the bearing on the heel of the angle be consid-



Assumed Stress Distribution on Rivets in Leg AC.

Assumed Stress Distribution on Rivets of Leg BC

Fig. 27. Fig. 28.

ered as concentrated at one end of the angle, the rivets into the girder in this locality should also be more highly stressed. Never-theless, with a rather stiff angle, some distributing effect can be obtained.

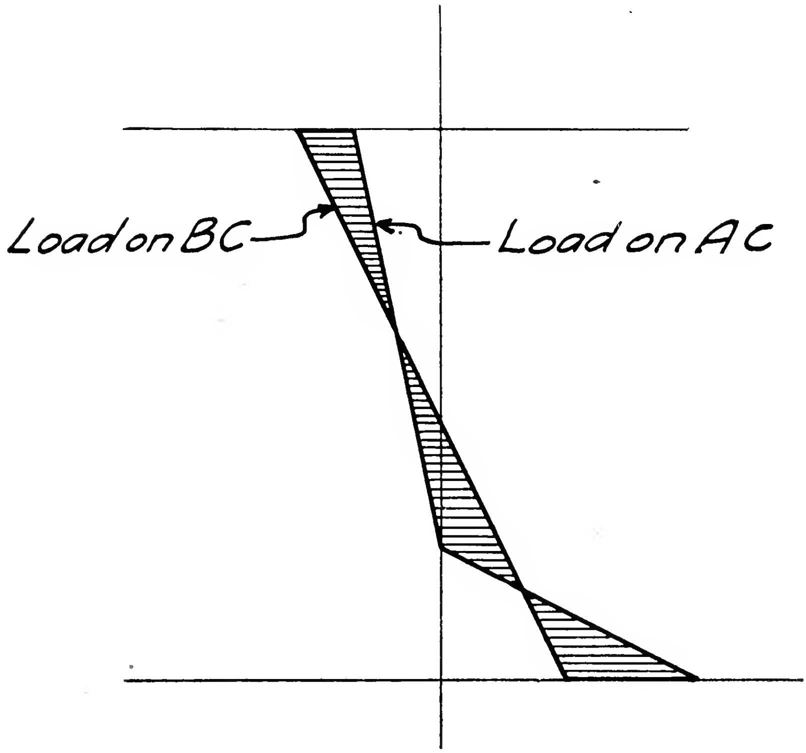
Referring to Fig. 27, and considering that tension in the rivets begins at the quarter-point of the connection angle, we have,

$$\frac{3\,S_2D}{8} = \frac{PD}{4};\ \text{or,}\ P = \frac{3\,S_2}{2}$$

We may then compute the resisting moment of this group of rivets by the usual assumption that the stress in any rivet varies

directly as its distance from the center of the group. In doing so, however, we may use an allowable stress in the extreme rivet of $\frac{3}{2} S_2$.

In all of the preceding, a full degree of fixedness of the angle at both legs has been assumed. If something less than this be assumed, the values of S_2 will become larger and will approach



Shaded portion indicates resulting loading on angle producing bending in a vertical plane under previous assumptions as to distribution of Stress.

Fig. 29

unity as the fixing moment approaches zero. The effective value of the rivet as given in the following table has been obtained by multiplying the value of S_2 by $\frac{3}{2}$ and then arbitrarily increasing this result somewhat. This increase, it is thought, is justifiable inasmuch as the fixing moments will always be something less than full fixedness.

As the fixing moment, M_1, becomes less, the moment at the root of the angle becomes larger. The thicknesses of the angles as previously computed are, therefore, ample, though somewhat less than full fixedness is obtained.

The rivets in the leg against the girder are also subjected to combined stresses as well as those in the outstanding leg. It ap-

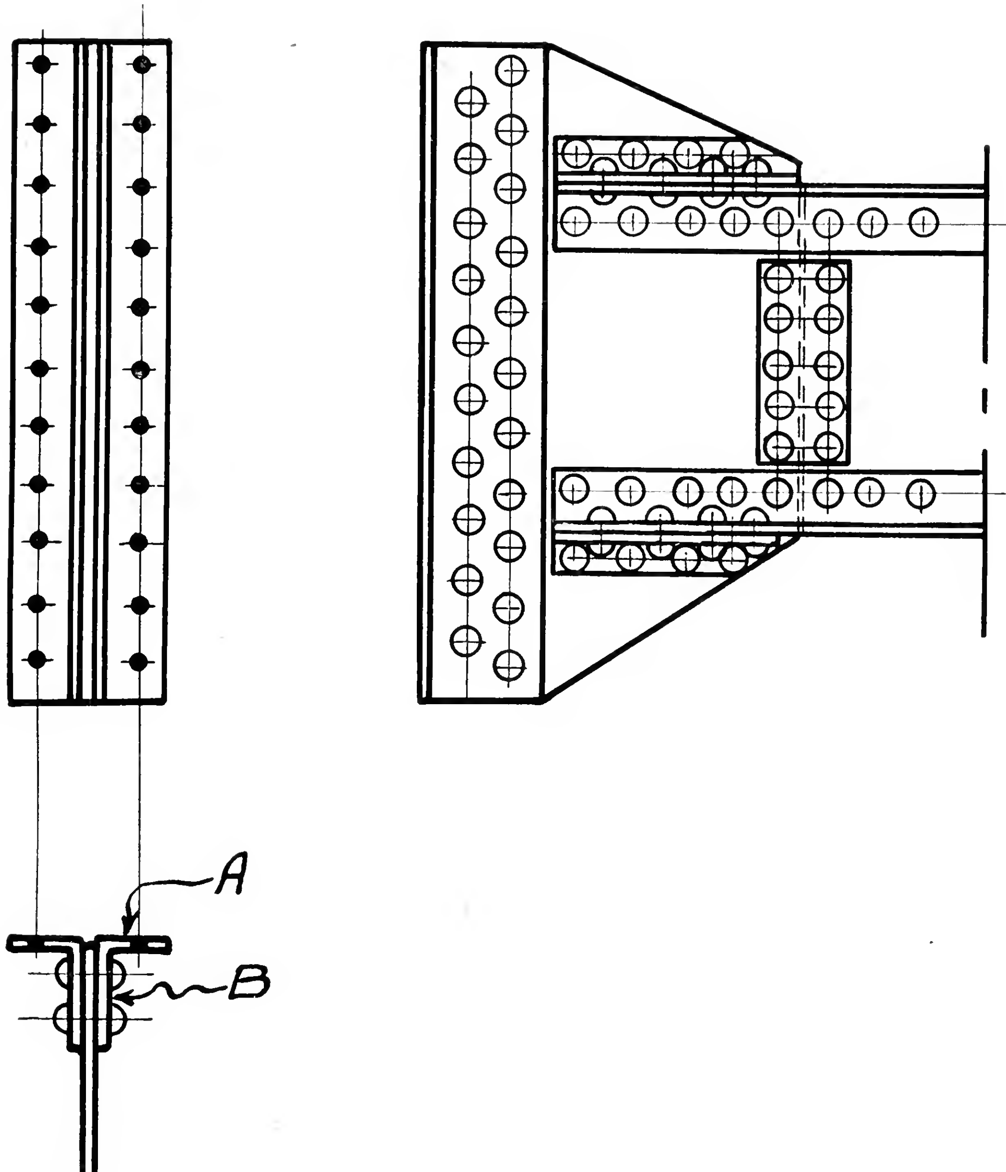


Fig. 30

pears advisable, in order that the rivets in the outstanding legs will determine the strength of the connection, to make this connection (as usually computed) somewhat stronger than would be indicated by the actual moment requirements. Inasmuch as this connection will permit two lines of rivets in the angle, this may very readily

be done. It is proposed, therefore, that this connection be made about 20 per cent stronger than that actually required for the development of the moment.

RESUMÉ.

Side Connection Angles. See Fig. 30.

OUTSTANDING LEG.

The rivets should be proportioned under the assumption that the stress in any rivet is directly proportional to its distance from the center of the group.

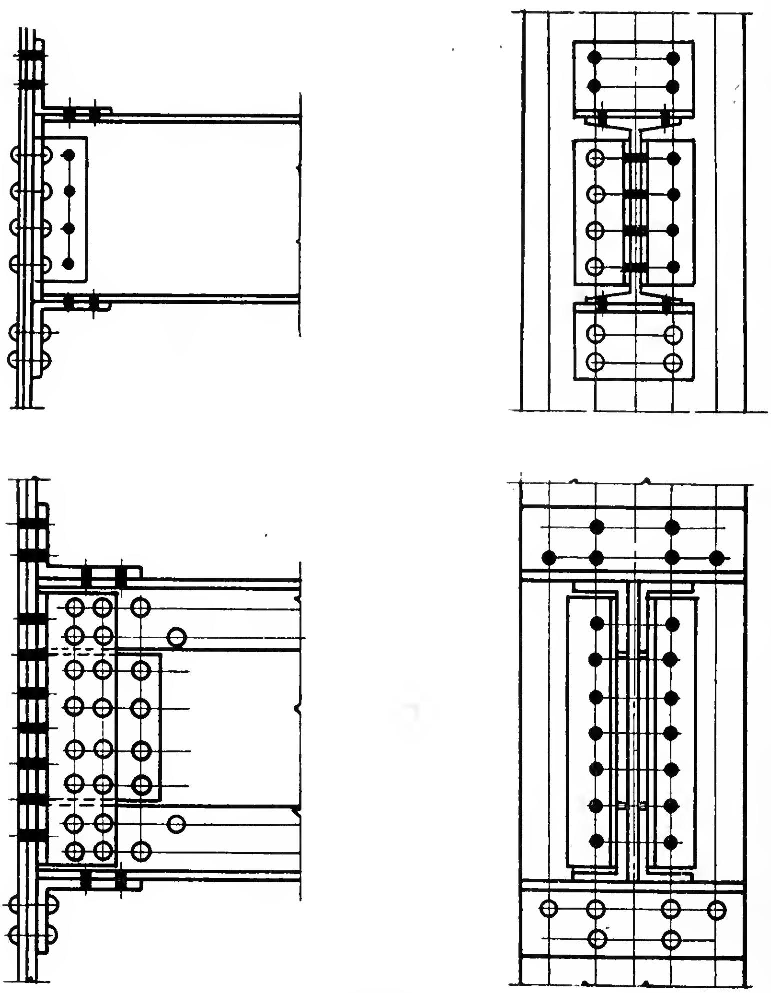


Fig. 31

With a given value as the allowable tension on the rivet (for wind bracing purposes this value is commonly taken from 1¼ to 1½ times the single shear value), the effective value of this tension should be made dependent upon the gauge of the angle and should be not greater than that given in table 1.

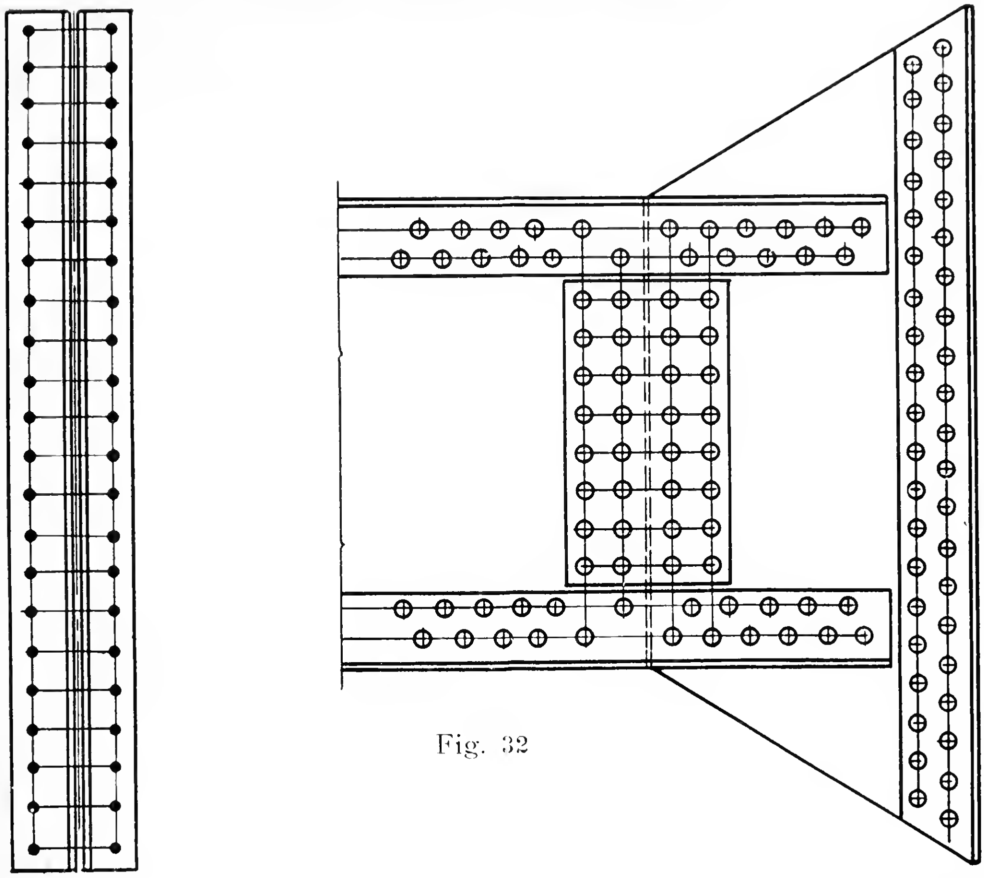


Fig. 32

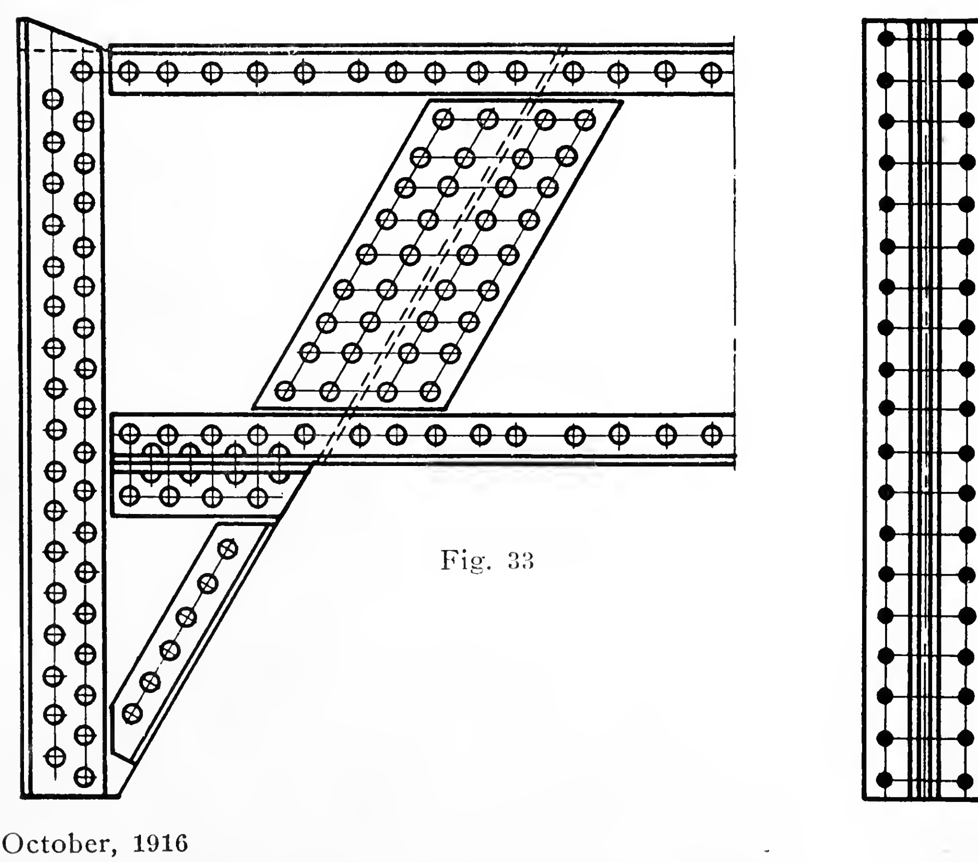


Fig. 33

When the vertical shear is comparatively large, it should be combined with the horizontal shear (in the usual cases, this may be taken with sufficient accuracy as ¼ the total tension on the rivet) and the tension in the rivet be correspondingly reduced.

One line of rivets in each outstanding leg should be considered effective for wind bracing.

The gauges in the outstanding legs should be as small as possible and should be made equal in both angles.

The thicknesses of the angles should be proportioned according

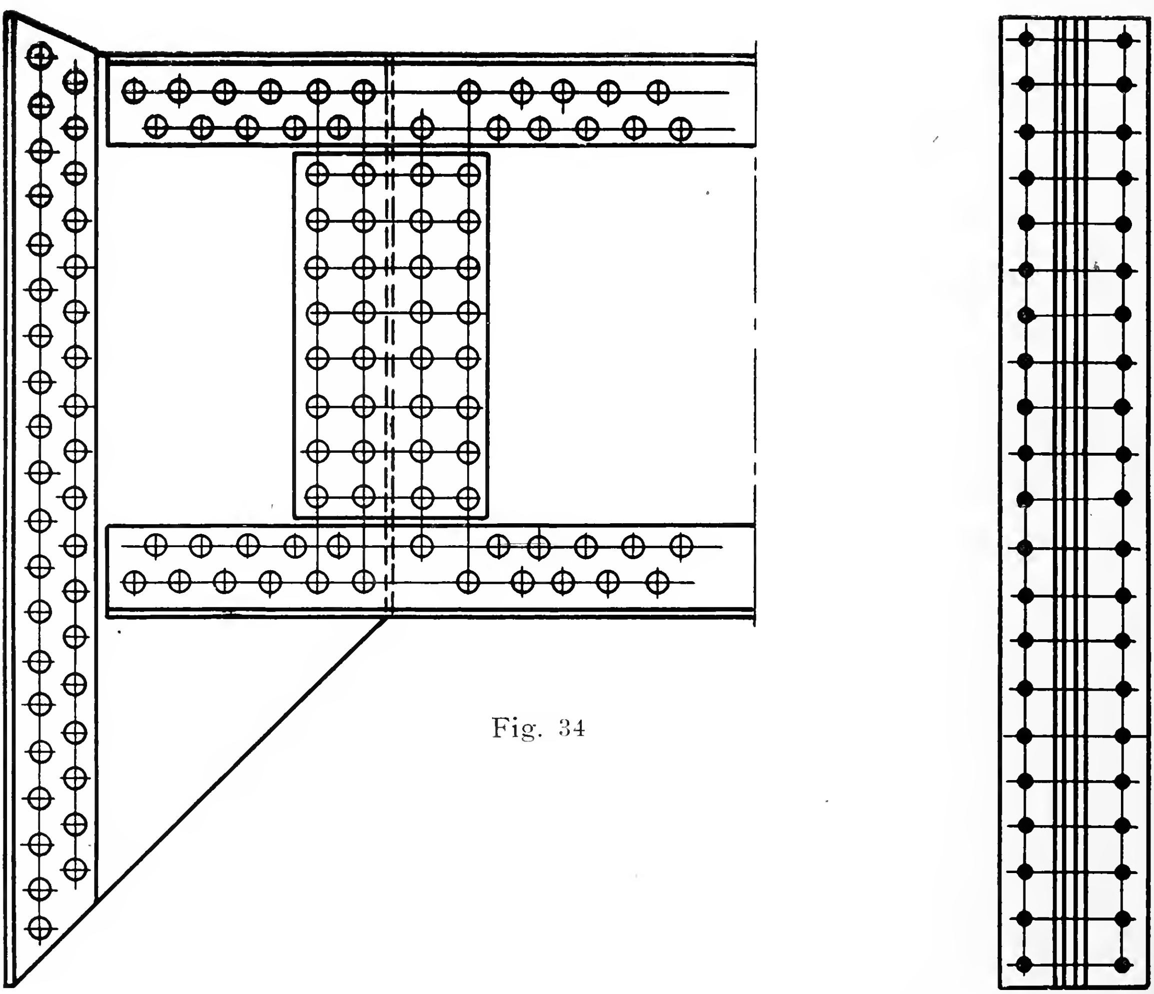


Fig. 34

to the gauge in the outstanding legs and should not be less than indicated in table 1.

Field rivets and shop rivets should be figured for the same unit stress, and this unit stress should preferably be that of field rivets. (This is advisable, for field and shop rivets, as shown on the design sheets, must often be interchanged on account of erection conditions.)

Leg connecting to girder.

This leg should be quite stiff and should, therefore, in general contain two lines of rivets.

The first gauge line should be made as small as possible.

The rivets should be proportioned under the assumption that the stress in any rivet is directly proportional to its distance from the center of the group.

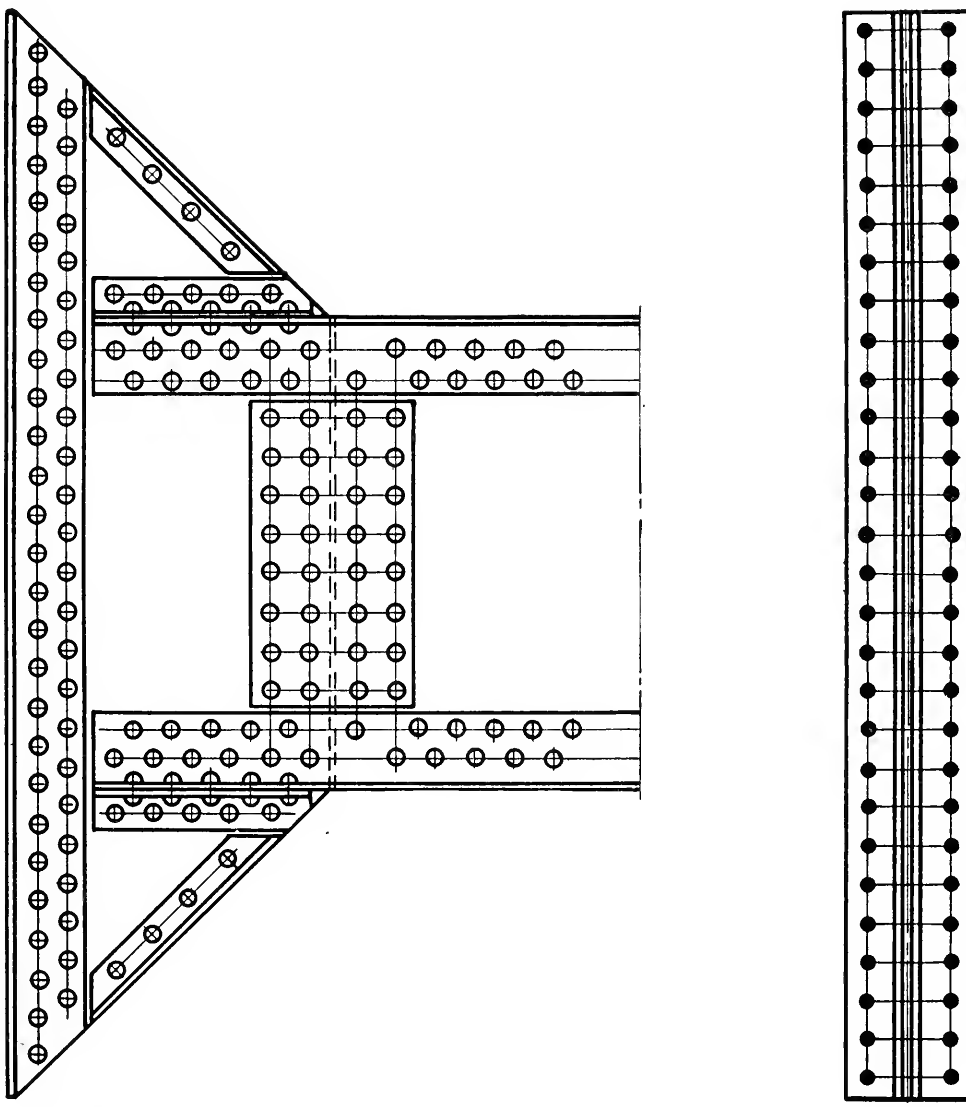


Fig. 35.

Proper allowances should be made for the vertical shear.

The computed strength of this connection for moment should be about 20 per cent greater than that for the outstanding legs.

TABLE I.

THICKNESS OF CONNECTION ANGLES.

Gauge	¾″ ⌀ rivet	⅞″ ⌀ rivet	1″ ⌀ rivet	Effective value of rivet in O. S. L.
1½	$\frac{9}{16}$	⅝	¾	1.00
2	⅝	$\frac{11}{16}$	$\frac{13}{16}$	.90
2½	⅝	¾	$\frac{13}{16}$	.80
3	$\frac{11}{16}$	¾	⅞	.70
3½	$\frac{11}{16}$	$\frac{13}{16}$	⅞	.65
4	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{15}{16}$	.60
4½	¾	$\frac{13}{16}$	$\frac{15}{16}$	.60
5	¾	$\frac{13}{16}$	$\frac{15}{16}$	.55
5½	¾	⅞	$\frac{15}{16}$	.55
6	¾	⅞	1	.50
6½	¾	⅞	1	.50

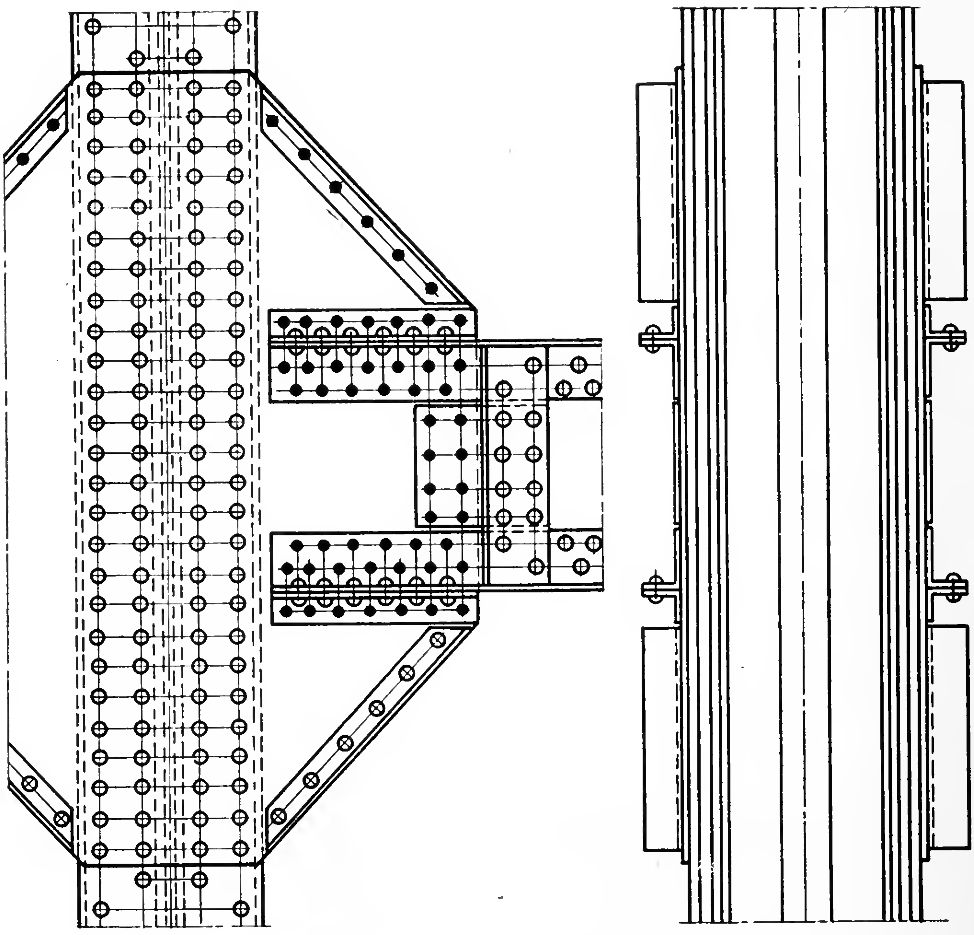


Fig. 36.

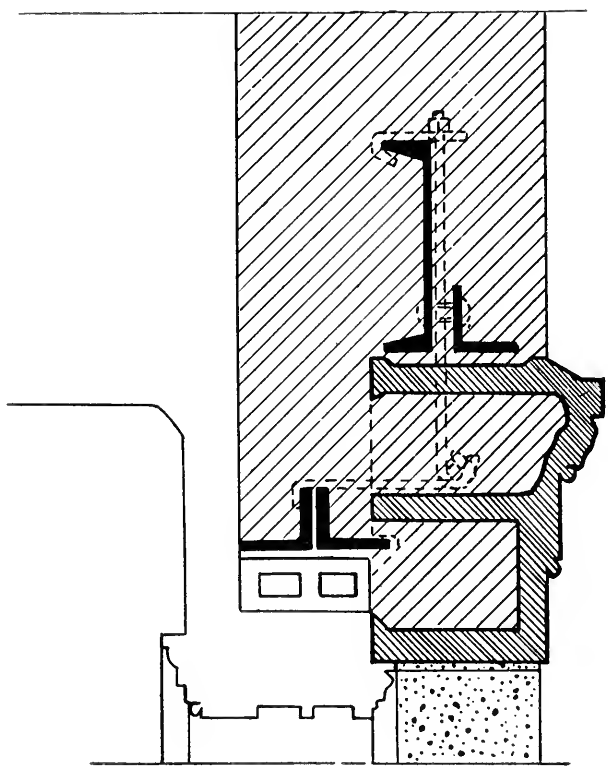
When gusset plates are used, care should be taken to see that the development at the splice is sufficient for the moment at that point.

Top and Seat Angles.

It appears that the equilibrium conditions of the side connection angles are applicable, with but slight modifications, to this type. The same continuous action of the connecting lugs should take place. The results may, therefore, be applied directly.

The effective value of the rivets should be about as given in table 1.

These angles should not be less than 6x6 and should have two lines of rivets in each leg.



SECTION THRO. LINTEL & SOFFIT.

Fig. 37

Only that line of rivets nearer to the girder should be considered effective.

The thickness of the angle should be proportional to the gauge in the outstanding leg and should be as indicated in table 1.

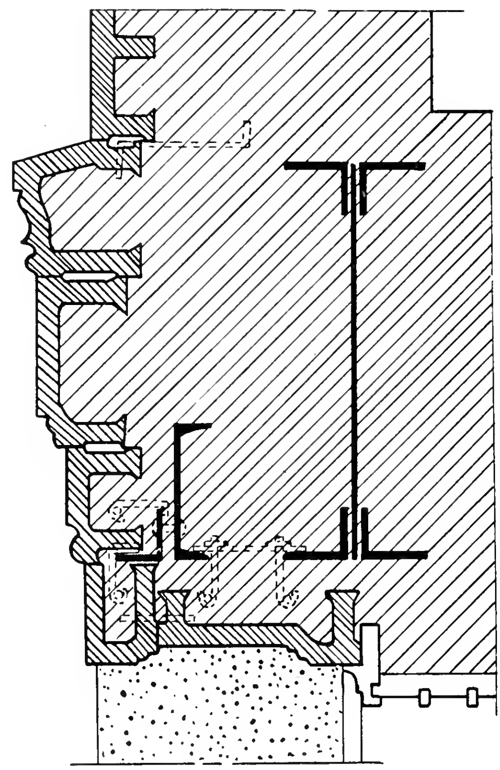
The following Figs., 31 to 36, show some typical wind bracing connections.

The types shown in Fig. 31 require the least amount of shop

work and should, therefore, be given the preference. The moment value of these types can very often be increased by using larger sizes of rivets. For columns with two or more covers, there is no objection to using ⅞ in. or 1 in. rivets.

Type 32 is the next in order of desirability.

Fig. 33 shows a type which is sometimes used but due to the diagonal cuts on the plates and holes for rivets not being lined up for punching makes the fabrication expensive. This type could be simplified by the use of the design shown in Fig. 36.

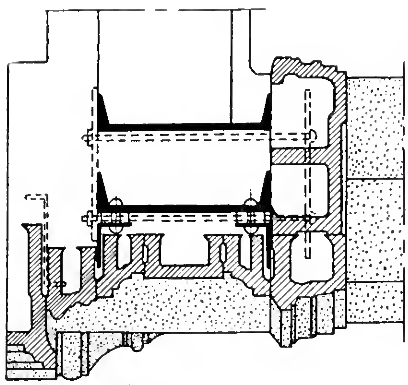


SPANDREL SECTION THRO' WALL.

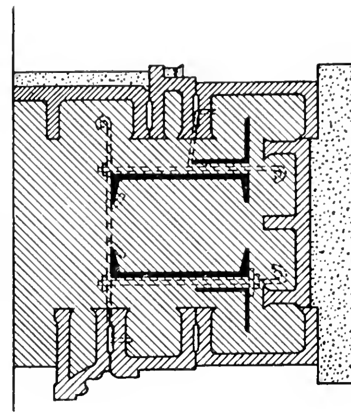
Fig. 38.

Fig. 34 shows a type which is used for the largest moments. Such wind bracing is often required at the lower floors where the columns are heavy. By changing the rivets to 1 inch diameter in the connections, it is often possible and advisable to use one of the types shown in Fig. 31.

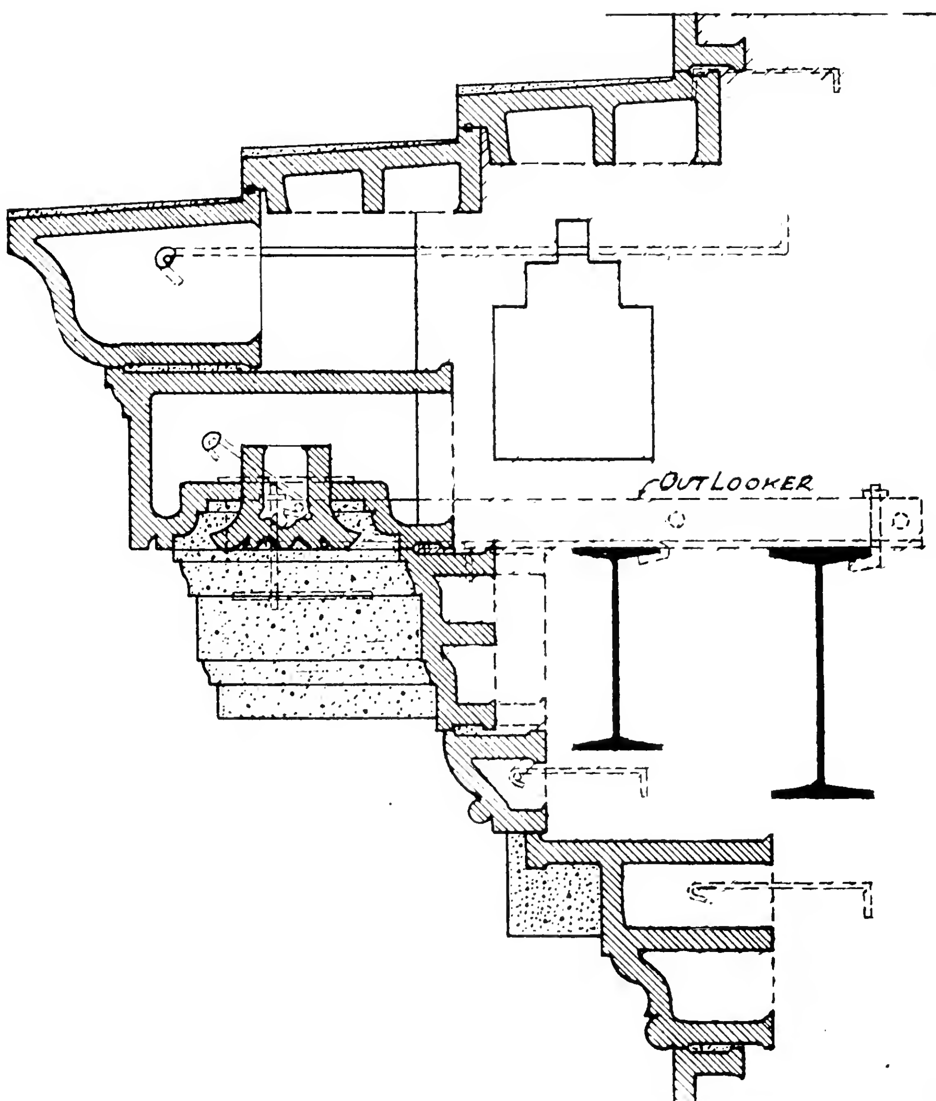
In Fig. 35, the two girders are in line with the flanges of the column. This type should be avoided because of the difficulties of manufacture and erection.



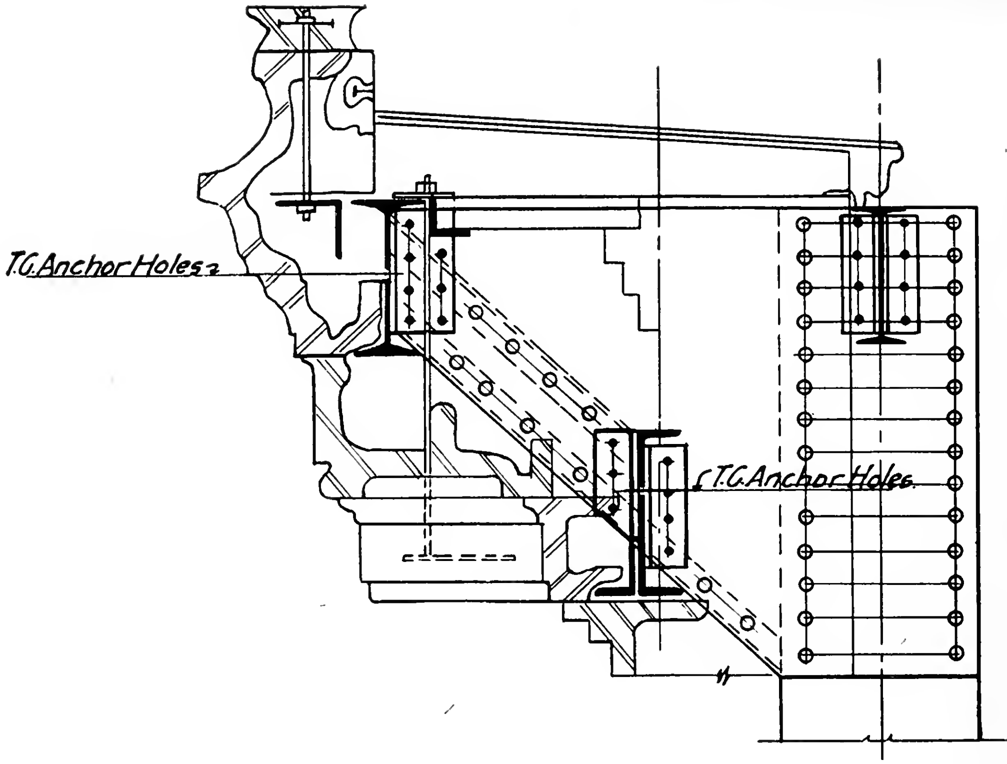
SPANDREL SECTION SHOWING METHOD OF SUPPORTING TERRA COTTA.
Fig. 39



SECTION OVER ENTRANCE SHOWING METHOD OF SUPPORTING TERRA COTTA.
Fig. 40.

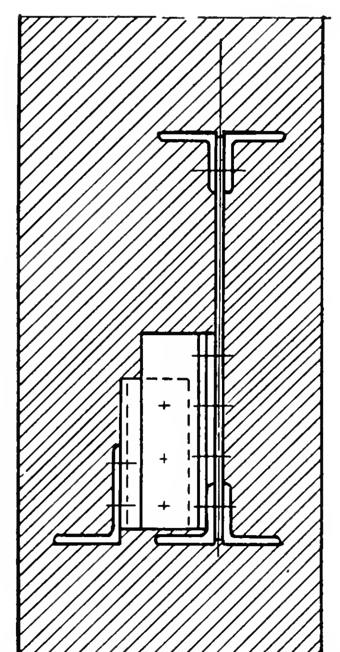


Section Through Cornice
Fig. 41



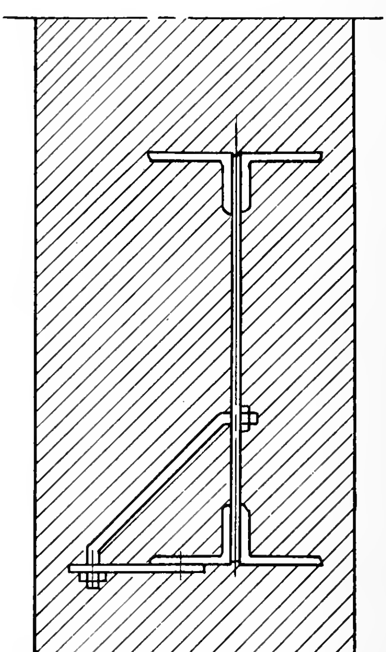
SECTION THROUGH CORNICE

Fig. 42



SPANDREL SECTION
FOR SOLID WALL.

Fig. 43.



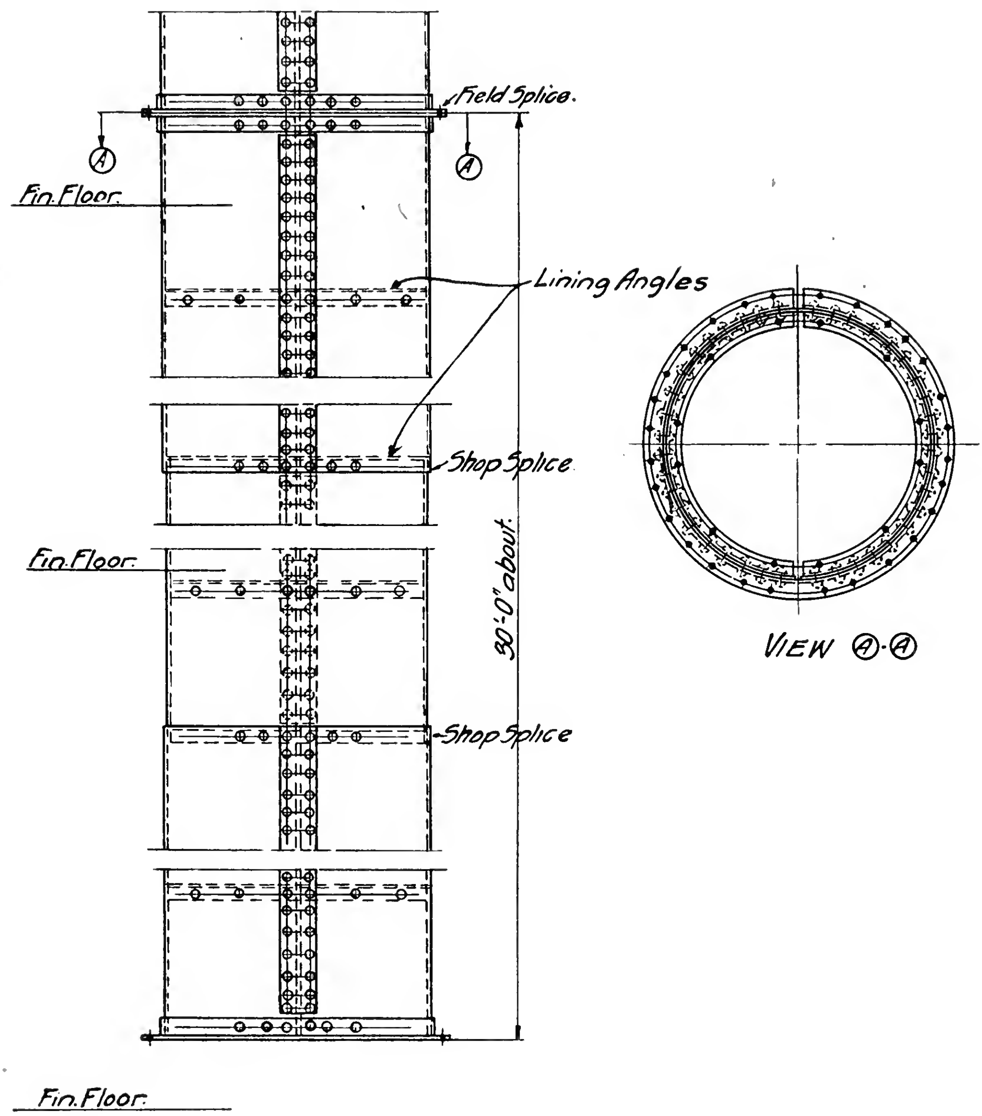
SPANDREL SECTION.
FOR SOLID WALL.

Fig. 44.

Wind bracing details should be kept as nearly alike as possible. Wind bracing brackets should not be changed for one or two rivets. By changing the connection for three or four rivets only, the brackets for four or five floors can very often be kept alike.

SPANDREL BEAMS.

The spandrel beams or girders are used quite often as wind bracing girders for the reason that the exterior walls permit the



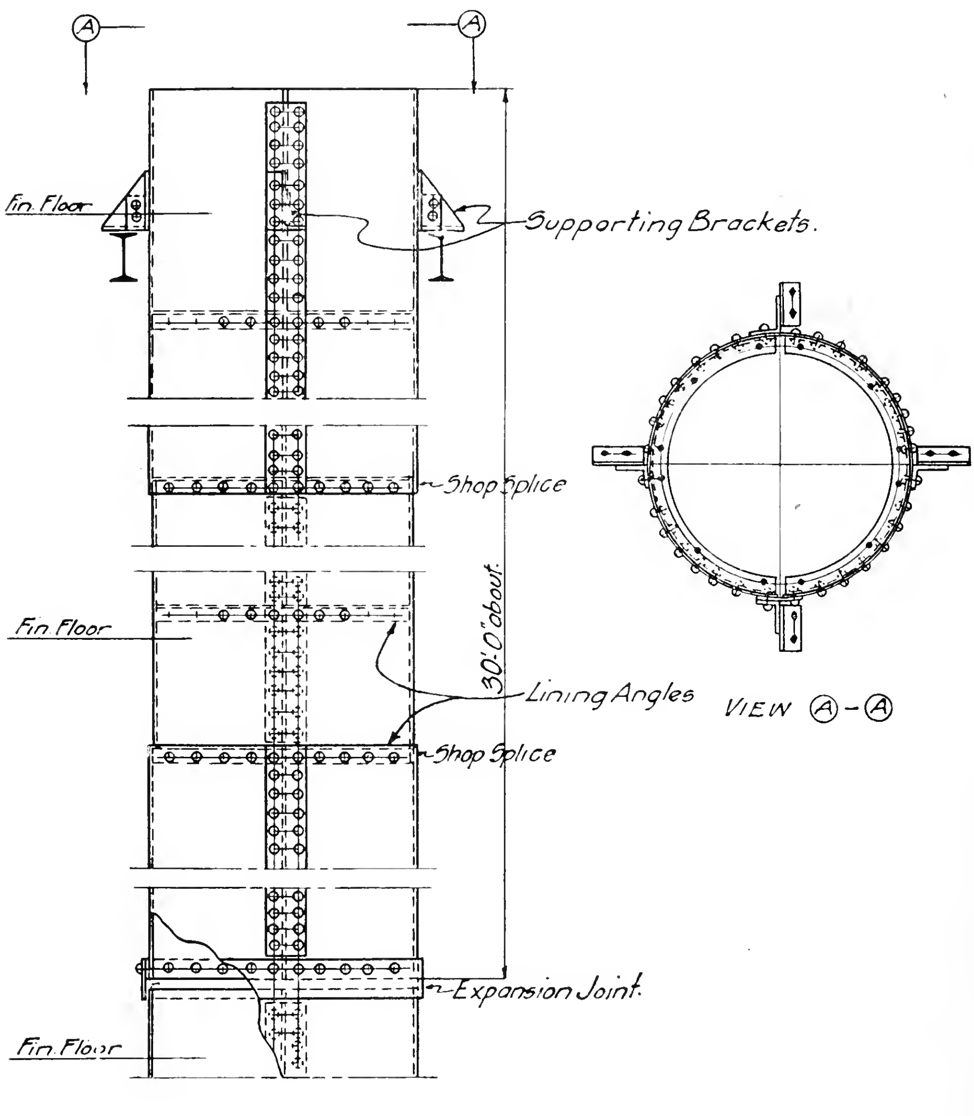
TYPICAL STACK AND DETAILS.

Fig. 45.

use of large gusset plates without interfering with architectural features. The requirements for supporting and anchoring the terra cotta finish cause a great many additional details on these girders.

These factors combined usually make the spandrel beams very complex for detailing and fabrication.

It has occurred to the writer that many of the details are more involved than are actually required to meet the conditions. With this in mind he has included a number of sketches, Figs. 37 to 44



TYPICAL STACK WITH EXPANSION

Fig. 46

inclusive, some of which have been reproduced from "Standard Construction, Architectural Terra Cotta," issued by the National Terra Cotta Society. Some of these sketches have been somewhat modified in order to make them applicable, and are intended to show

only the methods used to support the terra cotta from the spandrel beams.

These figures are typical and are intended to illustrate in a general way what details are desired by the terra cotta people. A feature quite predominate in all the sketches of this book is the absence, or at least the little occurrence, of open holes for the connection of the terra cotta.

The structural details have been so arranged that anchors and supports may be placed where desired. This feature should be introduced wherever conditions will permit, as it thus relieves the terra cotta people of the necessity of making connections and placing anchors at fixed points.

The ordinary terra cotta cornice is probably best handled by a system of angle out-lookers. These angles, riveted in pairs with a space between for the placing of anchors, are placed at each joint of the terra cotta block. These outlookers should not be riveted to the beam but should be fastened to the anchor beam by some sort of a hook bolt, so that lateral adjustment may be made to meet the joints of the block. See Fig. 41.

Cornices are sometimes designed as shown in Fig. 42. The spandrel beams and channels carry the terra cotta, and are punched in the webs for terra cotta anchors. This punching adds to the expense in fabrication and does not permit of as much adjustment in the field as the type shown in Fig. 41.

EXTRACTS FROM BUILDING ORDINANCE.

INTERIOR STEEL STACKS.

574. *Metal chimneys in fireproof buildings.* Internal chimneys of rolled steel or iron may be built in buildings of fireproof construction, provided that the rolled steel shall be not less than three-eighths-inch in thickness, except that the upper fifty feet of such chimney may be one-quarter of an inch in thickness, riveted in every joint, or of cast iron, providing same shall not be less than three-fourths inch in thickness and jointed by bell and spigot joints or flanged bolted joints. All joints in cast iron work shall be filled and pointed with fire clay. Such metal internal chimneys shall be securely and firmly anchored to the framing of such fireproof building at each floor line and at the roof. The lower part of each such chimney shall be lined with insulating lining for the height herein required for the respective area.

(c) Internal metal stacks on fireproof buildings shall be surrounded by continuous air space from the lowest story through the roof not less than four inches across at any point, and said air space shall be surrounded by brick, hollow tile, or reinforced concrete. No structural metal in such air space shall be without such fireproof covering.

577. *Height of chimneys above roof.* The height of all chimneys and flues of stoves used for domestic purposes or open fire places shall be not less than five feet higher than the highest point of the roof of the building of which they are a part.

(b) The height of all chimneys and flues above the highest portion of the roof of which they are a part, where such chimneys or flues are used for other than domestic purposes or for open fire places, shall be determined by dividing the greatest diameter in inches by four, and the quotient thereby obtained in terms of feet, with five feet added, shall be the minimum height

from the tops of such chimneys and flues above the highest portion of roof of the building. In no case shall the height of any chimney or flue be less than five feet above the roof of the building of which it is a part.

(c) The sum of the horizontal distance of any wood tank, pent house or roof house, on the same building of which any chimney shall be a part, and the vertical distance of top of such wood tank, pent house or roof house, on the same building to a horizontal plane passed through the top of the chimney shall not be less than one and one-half times the required height of the top of the chimney above the roof. The tops of chimneys within a radius of twenty-five feet of any wood tank, pent house, or roof house, on the same building of which such chimney shall be a part shall be at least as high as the top of said wood tank, pent house, or roof house. The tops of chimneys on ridge roofs shall be not less than three feet above the ridge.

578. *Insulating cavities.* All flues having a greater area than four hundred square inches shall be lined on the inside with an insulating material, which lining shall start at least two feet below the smoke inlet and shall extend upwards for at least ten times the diameter of the flue, or if said flue is not circular or square in cross-section for ten times the average diameter, when the flues are of brick, stone or concrete, said insulating lining shall be fire-clay brick or fire-clay blocks, and if such bricks or blocks are four inches or more in thickness, they may be considered as a portion of the thickness required for the surrounding walls. The walls surrounding chimneys having an area greater than four hundred square inches shall have an insulating cavity not less than three inches wide surrounding the inner four inches of fire brick or fire-clay blocks, for not less than the height required above for insulating lining and said inner core shall be built independent of the surrounding brick work and shall be free to expand or contract.

580. *Insulating material for metal chimneys and metal stacks.* Fire-clay brick or fire-clay blocks may be used for the insulating lining of metal chimneys and stacks, but not of a lesser thickness than two inches. The material shall be increased in thickness or supported on structural steel ledges and the material shall be stressed not to exceed the safe limits of stress elsewhere herein fixed for the material, or metal chimneys and metal stacks may be lined with blocks of magnesia insulation or with fused asbestos board insulation, or metal stacks or chimneys may be lined with any other insulating material tested and approved by the Commissioner of Buildings.

(b) Magnesia blocks insulation shall contain not less than 45 per cent of magnesia and 50 per cent asbestos, fibre formed into blocks not less than one and one-half inches in thickness by hydraulic pressure. After said magnesia blocks have been set, they and all metal bands and ties exposed with the flue shall be plastered with cement not less than one-half-inch in thickness on one-half blocks, and one-fourth-inch in thickness on one and three-fourths-inch and thicker blocks.

(c) Fused asbestos board shall be made of alternate flat and corrugated sheets of asbestos board, cemented together and fused under a heat not less than 1,000 degrees Fahrenheit to a minimum thickness of one and one-fourth inches. After said fused asbestos boards have been set into the flues, they and all exposed metal bands or ties shall be pointed with cement.

(d) Such magnesia block, fused asbestos boards, pointing cement and any other insulating material approved by the Commissioner of Buildings shall resist the disintegrating, dissolving, or diminishing of moist steam and the acid and gaseous fumes present in the flues at any degree of heat obtainable by the combustion of the fuel used.

INTERIOR STEEL STACKS.

Interior stacks are fully protected from any wind action and it is necessary, therefore, to design them for dead load only. This dead load consists of the weight of the stack material plus the fireproofing lining.

The stack, in the moderately high buildings, is generally made entirely self-supporting. It rests upon an appropriate base set in masonry. The stack is braced to the structural steel frame, usually at alternate floor levels. This bracing consists of abutting angles connected to the adjoining floor beams and are not connected to the stack, so that the latter is free to expand and contract independently of the steel frame.

In self–supporting stack, it is necessary to provide sufficient rivets in the base angle to properly transmit the entire load. The stack sections are most conveniently made in two story lengths. Flange angle splices are perhaps the most satisfactory, as the field rivets are all on the outside of the stack proper and permit, therefore, comparatively easy driving.

Figure 45 shows a self-supporting stack.

The stack in extremely high buildings is generally supported by the steel frame. The stack is usually constructed in two-story lengths, and each section is supported independent of the other. The supports commonly consist of brackets riveted to the stack and resting upon the floor beams. An expansion joint is provided at each section and is made by the means of a horizontal splice plate which is riveted to the lower end of the section and surrounds but does not connect to the lower section.

This type of stack has some advantages over the self-supporting type. Any section may be removed and replaced without disturbing the remaining sections. Erection may start at any floor, and no field bolting or riveting is required by the stack.

Figure 46 shows a typical stack which is supported by the structural steel frame.

Support for the fire-proof lining is usually provided by riveting shelf angles on the interior of the stack. These shelf angles are very light and are spaced about three feet apart.

The vertical shop splices of the stack should be butt joints and the horizontal splices lap joints. The shipping sections of the stack should not be made with more than two shop splices, thus using the maximum length of plates rolled and eliminating as many rivets as possible.

EXTRACTS FROM BUILDING ORDINANCE.

ROOFS.

The following paragraphs from the building ordinance cover this subject:

598. *Height of buildings.* No buildings shall be erected to a greater height than two hundred feet from the sidewalk level to the highest point of the external walls; provided, however, that buildings may be erected of a height of two hundred sixty feet from the sidewalk level to the highest point of external walls up to and until the first day of September, 1911, where a permit has been secured therefor and the work incident to the erection of said building has been begun before September 1, 1911. The erection of parapet walls or of ballustrades constructed entirely of incombustible material shall be permitted above the roof level of buildings of all classes, in addition to the height fixed herein for the same.

(b) The height of fireproof buildings shall be measured from the average grade of the street frontage of the building to the top of the highest point of the external bearing walls.

(d) Roof houses for elevators, tanks, skylights or scuttles may be built above the height of the main roof.

644. *Roof Slope.* In the case of buildings which are fireproof in their construction, the roof may rise above the limit of height of wall fixed by this ordinance for such buildings at a slope not to exceed thirty degrees with the horizon, and to a height not exceeding twenty feet above such limitation of the height of the wall. The space inclosed by such roof above the limitation of the height of such wall may be used as an inclosure for pipes, ventilating or elevator machinery or ventilating ducts, but it shall not be lawful to use such space for purpose of storage, business or residence.

516. *Live Load.* The roofs of all buildings shall be designed and constructed in such a manner that they will bear a load in addition to the weight of their structure and covering of at least twenty-five pounds per square foot of horizontal surface.

ROOFS

Most of the modern office buildings of this city are built up to the height limit as fixed by the ordinance, and advantage is taken of the provision permitting roofs to be carried above this limit. These buildings contain, therefore, about sixteen stories and an attic space.

The roof construction is usually the same type as the floor, though somewhat lighter, and may, therefore, be any of the types as shown under floor construction.

Provision is made on some buildings for the future construction of additional stories. In such cases, the roof serves as one of the future floors and is designed accordingly. The columns are properly punched and the ends finished to receive additional sections. Such work, as sloping roof beams, cornice details, etc., which must later be removed, is connected by bolts so that it may be readily removed without injuring the permanent construction.

THE ENGINEERING SOCIETY—ITS PAST, PRESENT AND FUTURE ACTIVITIES*

By Ernest McCullough, M. W. S. E.

Presented September 20, 1915.

A little over a century ago the men engaged in works of civil construction organized a society and called it a society of civil engineers. The right to assume the title of engineer was contested by the only men to that time recognized as engineers, that is, the men engaged in military engineering work, and it became necessary to define a civil engineer when the society finally applied for a royal charter. The result was the incorporation in 1828 of the Royal Institution of Civil Engineers of Great Britain, civil engineering in the charter being defined as "the art of directing the great sources of power in Nature for the use and convenience of man."

In the United States in 1824 the Rensselaer Polytechnic Institute in Troy, N. Y., began giving a course in civil engineering, the only other school doing similar work at that time being in France, where engineers were trained for the public service to construct and maintain roads and bridges, this school being an offshoot from the school of military engineering. Years elapsed before other similar schools were started, but today they are numbered by hundreds. That technical education is becoming popular is plainly evident and the great growth of engineering schools is shown in the following quotation from an article in Engineering News, July 4, 1912, by Professor Marburg, in referring to graduates of the University of Pennsylvania in the Department of Engineering:

"It may be of interest to add, that of the total number of graduates, 1,258, beginning with the class of 1873, more than one-half have graduated since 1904."

A study of the lists of graduates of more than fifty engineering schools in the United States shows practically a similar increase. For a number of years in the first half of the last century it was common to read on title-pages of books the term "Mechanical Civil Engineer," "Mining Civil Engineer," etc., the inference being that in those days all men not military engineers were civil engineers. The development in the manufacture of power brought about by improvements in the steam engine and the vast increase in railway building finally resulted in the distinct professions of Mechanical Engineering and Mining Engineering and later Electrical Engineering. Now the civil engineer is said in a late report of a committee of the Institution of Civil Engineers to have almost disappeared in the original meaning of the term. The men known as civil engineers are engaged in many special lines of work, so the multiplicity of specialties and the multiplying number of special societies is something requiring notice. Before the civil engineer was known

*Written discussion of this paper is invited.

as such there were road builders, bridge builders, canal builders, colliery viewers (engineers), surveyors and builders. The fundamental education in all branches being the same the development of industry has had the effect of re-creating the old sub-divisions, more highly trained perhaps, but conditions now are as they were before the engineer evolved as an entity.

The time has come when the engineering society should pause and consider if it is doing necessary work. The earlier societies performed a valued service. They brought together men having similar interests; where the older men read papers and discussed papers which were intended purely for instructional purposes, most of the engineers being trained by apprenticeship. There existed few schools and there was a demand for trained men. Young men picked up their knowledge as best they might in the offices of eminent practitioners, and at the society meetings met other men of experience. Thus they obtained the broad view of their business so necessary for future success. The educational value of the meetings was so great that a professional spirit developed and was fostered.

Then the great material development of the world commenced, the New Era so well described by the late Mr. Morrison in his little book bearing that title. The engineer became the technical man, his vocation recognized alongside the older professions of law, medicine and theology, so it is no longer a reproach for a man to be called an engineer, but rather an enviable title. We are living in that era.

The technical, or engineering societies have not developed with the work of the engineer. They still consider themselves as institutions organized solely for educational purposes. This is the way they are conducted, but the majority of the members know many societies exist rather as an evidence of the standing of the members than for their declared purposes. The modern technical journal is doing more real educational work than any society, no matter how large or how important it may be. The pages of the weekly and monthly papers bring to us news from the front fresh, and in a way which the more formal papers of a society cannot. Our society proceedings are become encyclopedias which are consulted less frequently than are the pages of the journals maintained purely for profit.

Some societies are beginning to realize that something is lacking in the old methods and this is shown by the growth of social activities. That there is a real demand for this side of the training of a technical man is proven by the societies which feature the social side. The Western Society has not grown much for five years in membership, while the attendance at the meetings has grown enormously, due to its social activities.

The young man is the central idea of the present policy of the Western Society, beginning with the new constitution of 1911,

which provided for a grade known as Student Members. May it not be asked if the central idea of the original technical societies was not the young man? Granting that he was the reason for the inception of such societies, we can ask ourselves if we have been for some time treating him fairly. Are we now taking proper notice of him and the increased difficulties attendant upon his endeavors to secure a foothold in his chosen work with the increase of competition following upon the great development of the engineering school and the popularity of technical training today?

The young man feels he has not been paid the proper attention. There is a well founded idea that engineering societies have for many years past been mutual admiration societies of successful men, and used for furthering of insidious advertising by men qualified to take full advantage of the position their membership brings them. The discussions at the meetings are too frequently inadequate and real criticism is seldom developed when the author of the paper is of commanding eminence. Some men even use the society to which they belong for exploiting patented processes and materials. The young man learns something from the papers, but he feels diffident about discussing them, as he fears his opinion would not be well received. "Get a reputation first," is the attitude of too many authors when they write a closure to a discussion.

The young man does not want this. He wants fellowship, companionship and definite recognition. He is glad to attend a meeting where he knows refreshments will be served, not because of the refreshments, but because something to eat and drink signifies a lack of formality and perhaps an opportunity to mingle freely with older men who have made their mark. He wants to make acquaintance with men having like interests with himself. He wants to feel that the society is more than an editorial body or an encyclopedic compilation of engineering facts;—that it is composed of flesh and blood men who want to help him because of their knowledge of the trials and tribulations he is undergoing. The older members have been over the ground and should help him. He would rather know how to obtain a position and how to hold it than to hear how other men have done engineering work, for he reads the technical journals and gets a surfeit of such material.

From time to time young men organize societies which are intended to help them meet their particular troubles. These societies generally start out with the idea that every educated man should be kept at work and the employment question is uppermost. They are generally organized as a protest against commercial agencies which obtain positions for technical men and charge large fees for putting the "jobless man in touch with the manless job." It is known that in many large offices the chief draftsman is a stockholder in such agencies and many discharged draftsmen think

they are but pawns of fate in the hands of men who profit by their frequent changes in positions.

No fee is charged in such societies for obtaining positions. The members, actuated by an altruistic spirit, intend that the dues shall support the enterprise. They all have the same end. They perish from off the face of the earth when all the members have positions and forget to continue paying dues. The societies are organized when times are hard and die when good times return, the successful members transferring their membership to the older, standard societies. While this is essentially the truth, the real underlying cause is that ultimately they come under the control of the I. W. W. of the engineering profession. Men imbued with the ideas of trade unionism get control and attempt to fix minimum rates of pay and impose conditions of employment to the end that technical work will be closed to all but a definite number. The result is that for the lower paid positions which require but a modicum of training, employers use high school graduates, thus throwing on the world an additional number of half baked competitors of properly trained men.

This year two such societies have been organized in Chicago. One is known as the Associated Technical Men, the other as the American Association of Engineers. Judging from my own mail I have no doubt all members of the Western Society have been regularly receiving printed matter from these societies. The aims and objects of the Associated Technical Men being too long to present in this paper, only the objects of the American Association of Engineers will be presented, for the two societies seem to be working towards the same end.

The objects of the American Association of Engineers are stated to be: "To raise the standard of ethics of the engineering profession and to promote the economic and social welfare of engineers."

These objects are to be obtained;—

1st. By affording means for the interchange of information.
2nd. By maintaining a service clearing house.
3rd. By affording patent and legal advice.
4th. By supervision of legislation.
5th. By proper publicity.

Wherein do the objects of the association and of our own conflict? If there is no conflict why is there such an association when there are several hundred technical societies already in operation in the United States?

The answer is that the older societies are not attending to this business. The work above outlined should be attended to by the veterans. "Old men for counsel, young men for action," should be the motto of the older societies. If this were the motto and lived up to properly the young men should obtain all the objects sought and the societies would grow faster than they are now growing. The members should receive the worth of their

money; the older men in the feeling of satisfaction following every worthy action, the young men in the experience of material benefit. In their turn the young members become old members and will pass the good work down to succeeding generations.

Discussing the methods above outlined, the older societies can honestly say only the first has been attempted by engineers.

That the second has not been properly attempted is a reproach. The engineer is a wanderer from job to job. When capital is active he is hard to find. When dull times come and capital rests, the streets are full of technically trained men out of work. They wander from office to office, many of them starving and too proud to admit it, many never getting a substantial footing. Their work is concerned with new enterprises and with the day laborer they share the ups and downs of fortune, helpless and frightened when they face the facts. One of the most bitter things is the inability to explain to their parents and families, for the popular idea of the engineer is that he is highly paid and always busy. There is a place for all and it is the duty of the older engineers to take care of these, their brothers.

Every day the Western Society, and the other large societies, delays in organizing a service whereby members out of employment can be placed in positions, is an inexcusable reproach. The organization is here; it requires only the spirit. There should be no employment agencies to charge high fees for obtaining positions. It should be a breach of ethics sufficient to dismiss a man from the society for any member to own stock in such an agency. It is a temptation to a man who controls the employment of others for him to own such stock. The only agency should be the society organized by technical men and supported by technical men. It should not limit its efforts in this direction to members, but should give members the preference, all things being equal. All members needing men should file their wants with the secretary of the society and not attempt in any other way to secure men until the secretary says there are none available. When this line of work is well developed there will come a time when the society can be of service to persons who wish to learn something about the standing of men in private practice, whom they may wish to employ. However, this is only an idea which may be worth little, for men in business for themselves can do their own advertising. However, all members might be classified by specialties and lists printed, so that parties wishing to get in touch with men in any special line of work may have such a list given to them by the society and then make a choice.

The third method, namely, the affording of patent and legal advice, needs to be approached with care. The society should have an attorney who can help members who have trouble in collecting pay,—that is, members who fall into the hands of unscrupulous employers. There are many such. There was organized a couple of years ago a society of authors to protect individuals against the

rapacity of certain dishonest publishers. It is said to have been very successful. Medical men have such means for collecting bad accounts and to protect them against blackmail, for a number of physicians and surgeons are annually attacked by former patients who know a man will often pay large sums rather than get undesirable notoriety. This side of the medical societies is so well taken care of that few accounts of such attacks ever get into the public press. It is understood that lawyers and ministers of the gospel have similar legal protectors, and some of us believe our colleagues, the architects, have a few societies in which the business side of the profession is properly cared for. Engineers should similarly protect themselves against attacks on character and attempted extortion or robbery. Just what the new association intends to do in the matter of patent advice I do not know, and supposedly the members have only a vague idea, but that there is some good reason for including this item we cannot doubt.

The fourth method is concerned with legislation for the technical man. The people of the United States have gone mad on the subject of legislation. They apparently wish to preserve the individuality so long a characteristic of Americans, combined with the socialistic condition which is the inevitable result of the passing of a large number of regulatory laws. It is not for us to object and stand too much on dignity. We must recognize the fact that a condition and not an hypothesis confronts us. The legal profession would not have the standing it enjoys were it not for the very thorough way in which the lawyer has intrenched himself legally. The medical profession did not enjoy the high standing it now has until legally it was protected from the men who otherwise would bring the profession into disrepute. The architects are working hard to obtain legislation to make architecture a closed profession, beginning with the passage of the license law for architects in Illinois in 1897. Now many of the states have similar laws, the greater number of which were passed the present year. Engineers, myself among the number, were opposed to legislation to license engineers, but conditions in the State of Illinois became so intolerable on account of the monopoly given to architects that we obtained this year the passage of a law to license structural engineers.

We attempted to have the lien law amended to protect engineers, for at the present time they are not protected. Architects are so protected, their society seeing to this item some years ago. The fight, however, for the license law was so strenuous that the lien law was not fought for hard enough, but we hope it will be looked after in the next session of the legislature. The Western Society should be now considered as committed to the supervision of legislation to avoid any such regrettable contests in the future with other professions as that with the architects the present year. The next piece of legislation to be attended to is one fixing the status of sanitary engineers or the plumbers will get ahead and obtain control of the design and construction of sanitary work. A

bill in the interests of the plumbers was prepared to be presented to the legislature at the session just closed which would have given plumbers a practical control of matters properly belonging to sanitary engineers. Not for the purpose of making a closed profession of sanitary engineering but to prevent injustice to such engineers because of legislation which may be secured by men in other lines of work it will no doubt be necessary to have examinations and licenses for them.

However, a better way will be to secure a law requiring the registration of professional engineers with an examining board qualified to examine men in different specialties so that the word "engineer" will possess a dignity comparable with the titles of the other learned and honorable professions, which stand high in the esteem of the public. Not only must the modern engineering society see that legislation is secured to protect and elevate the engineering profession, but it must also carefully look after proposed legislation to the end that no laws will get on the statute books which work harm to the people of the state. That is, as citizens, we must protect fellow citizens whose lack of knowledge of technical affairs leaves them at the mercy of special interests.

The fifth method is proper publicity. What is it? Proper publicity depends upon changing ideas and advances in civilization. That is, methods of publicity in one generation which are perfectly proper may be improper in a succeeding generation. The advertising methods of the live, wideawake business man may be considered coarse and unbecoming for the professional man. They are usually so considered. Is this idea a survival of a generation past? Is it, as many young men claim, a fetich worshipped by professional men for the purpose of helping older men maintain their preeminence and hold the young man back? The question must be answered individually just now, for the engineer, no matter how decently he may conduct his business, is frequently partly a professional man and partly a business man. When he is employed in a confidential manner and given a fee he is a professional man. When he is on a regular payroll he is a technical employee. When he assumes the direction of work he may be said to be a business man. Throughout his life the technically educated man, the engineer, is at times a professional man, a technical employee and a business man. He must do some publicity work, and societies should not be hide-bound in what is to be considered proper means of publicity to be employed by individual members. It should be enough for the societies if the members remain decent and bring no discredit on the work of the technical men.

The societies heretofore have concerned themselves with the publicity work of individuals. What is now a crying need is publicity work of a proper sort by the societies for the benefit of the membership, and, incidentally, of the technically educated men not members of any societies. Through proper publicity work all

technical men not members will want to become members. Incidentally the work of technical men will be so placed before the public that there will be an increase of good material in the ranks. Proper publicity should have the effect of sifting out desirable men from those not so desirable. It is due to improper publicity work that we have complaints today that there are too many unfit men now enrolled as engineers. These men, no matter how unsuited they may be to the work of the engineer, have a place somewhere in this world where they can fit in, and it should be a part of the duty of the engineering society of the future to find the hole into which these misshapen pegs may fit.

Permit me to quote from a circular issued by the American Association of Engineers under date of Aug. 1st:

"This association will be devoted to the best interests of the *average* engineer of good standing. *Not* to elevate the *already elevated,* but to bring up the standing of the *rank* and *file* to that attained in other professions. We solicit the support of the big engineer and employers of engineers and aim to command their respect through the above methods, and in the course of a little time (within your lifetime) secure the same standing for the commercial engineering profession as that enjoyed by the legal, medical and military professions—material compensation, consideration and self respect."

"Why is the average graduate in civil, mechanical, electrical, chemical or one of the dozen other engineering branches after five or ten years of labor in his chosen field, still treated with the consideration given to day laborers and no recognition given to his part in the big commercial achievement resulting directly through his efforts?"

"It is because there is no organized effort to show these results and they are being usurped by others. These men (you and I) are so concentrated on the technical points of our daily labor that we overlook the big fundamental law that 'he who does not speak for himself will be cursed by small praise.' We must have a *speaking trumpet* for the commoner. We need at least 5,000 of the 50,000 men who are doing the engineering work before we can expect to gain recognition."

Such printed matter distributed broadcast by young, energetic, well educated men, is a slap in the faces of the older men who attained standing in the days when competition was not so strong in technical work and who fail to realize that the engineering graduate of today is up against it harder than were the men of the generation immediately preceding. This sort of printed matter is not nice reading but it does represent the sentiments of thousands of young fellows who are earnest and are not yet anarchists or I. W. W. propagandists. It should waken all the older engineering societies so that improvements in conditions will come from the older men who have not forgotten the days of their own struggles. Let us help the men

who want help before they have a grievance, for the nursing of a grievance, real or imaginary, is harmful to the souls of men.

It is the duty of engineering societies to break away from precedent and get back to first principles. They must become again the places where the interests of the young men are the concern of the older men. They should not permit themselves to be classed as organizations for the elevation of the already elevated, a rather neat phrase, by the way, but they should be *in loco parentis* to the rapidly increasing family of technical men. The work should not be done in a patronizing way, but should be regarded as something that should be done. It is not an opportunity which is faced by the Western Society. It is a duty.

"I hold every man a debtor to his profession; from the which as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and ornament thereof," said Bacon. So long as reproach can be brought that the societies do little more than print papers and discussions dealing with physical facts and neglect to consider men the members are not ornaments to their profession. We must clear engineering of the charge that it is a most interesting profession but a mighty poor business.

DISCUSSION.

President Jackson: The writer of the paper has taken a very positive position in favor of various activities on the part of engineering societies such as those exemplified by the national engineering societies and our own society. Some of the suggested activities seem to me to be excellent, whereas some of them are very questionable to my mind.

It seems to me certain that one of the most important duties of an engineering society, even one of such technical character as ours, should be to bring the members together so that they will become truly acquainted, while at the same time giving something of an educational or inspiring character. There is no question in my mind of the need for close social acquaintance amongst engineers as a class. Also I believe that every engineering society may, as one of the best parts of its activities, establish an employment bureau such as has been established by our sister society, the American Society of Mechanical Engineers, with the idea of giving it the most careful and thorough attention, as suggested by Mr. McCullough. This, I believe, is one way in which an engineering society can be of great service to the profession, since anything that helps in bringing together more easily and surely the right men and the right places is of real benefit.

I do not believe that any technical society, such as ours, can with propriety maintain a legal department for the benefit of its members, but I do believe that the secretary of such a society should consider it a part of his duty to assist in every reasonable way mem-

bers of the society who are in trouble, and that this should also be considered as part of the duty of the officers of the society.

In the matter of technical societies such as exemplified by our national societies and our own society, being "committed to the supervision of legislation;"—there can be no doubt that these societies should keep carefully advised as to the probable trend of legislation which affects the engineering profession and the needs of legislation, and that they should lend all possible assistance in advising sanely and wisely those who are responsible for our legislation. But surely they should broaden their own constitutions if they are to enter the field of developing legislative propaganda and carrying it through. Furthermore, I believe that engineers should register their protest as a unit against permitting another situation to arise wherein it is necessary to have an engineers' registration law. The structural engineers' license law was an unfortunate necessity made imperative by previous unfortunate legislation. A general engineers' registration law will not raise the average of engineering proficiency nor increase the protection of the engineering client, and failing in these it would obtain no true advantage.

In the matter of publicity, this must, in my opinion, be a gradual evolution. The recognition of the importance and dignity of the engineering profession is undoubtedly progressing rapidly and we are likely to make a serious blunder if we move with too little caution along the line of publicity.

B. E. Grant, M. W. S. E.: Some of the statements of this paper need modification or elucidation before they can be accepted literally. The first impression that one might get from the paper is that engineering societies have failed seriously in the objects for which they were organized. It is not an uncommon thing for members to misunderstand the objects of an organization and to think that because it does not undertake every kind of activity that is proposed for it, that it is a legitimate subject for criticism. The objects of our own society, as stated in the Constitution, are "the advancement of the science of engineering, and the best interests of the profession. Among the means to be employed shall be meetings for the reading and discussion of appropriate papers and matters of engineering interest, and for professional and social intercourse; the collection of a library, and the publication of such parts of the transactions as may be deemed expedient."

The objects of other engineering societies are essentially the same as those of the Western Society of Engineers, with the exception that some of them are not so broad as the Western Society of Engineers, in that they are devoted to some branch or specialty of engineering, such as mechanical or electrical engineering. The history of the older societies is one of steady growth and continued success along the lines of their original purpose.

One of the misconceptions of the function of an engineering

society is that it ought to publish a technical journal in competition with the commercial weekly and monthly periodicals that already cover the field of news in an excellent manner. The commercial periodical is primarily a newspaper and has many of the limitations and weaknesses that go with that fact. The society publication does not aim to be a newspaper. It seldom reports an event immediately after its happening, and more rarely still does it give advance information of an event.

The author says, "Some societies are beginning to realize that something is lacking in the old methods, and this is shown by the growth of social activities." As a matter of fact, the growth of social activities, with the Western Society of Engineers, at least, has been more apparent than real. Ever since the founding of this society, the social side of its life has had expression in one way or another. At times it has seemed to have had rather undue prominence, and the emphasis recently given to entertainment by our society has been a case of history repeating itself, and with the usual result. Whenever the energy and resources of the society are expended upon forms of social activity, the other and important lines of work of the society must suffer. Meetings which offer good entertainment will usually have a large attendance, and this large attendance will greatly increase the average attendance for the year, and at the same time may indicate absolutely nothing as to the value of the meetings to a technical society.

Undoubtedly the society should occasionally relax and give its members an opportunity to meet in a social way and become better acquainted with each other, but the society should not try to take the place of a club when it has neither the facilities, resources nor objects of a club.

The author makes a plea for the young man, apparently meaning by that terms the recent graduate. The Constitution of the Western Society of Engineers makes provision for the young man even before he graduates. It, in fact, provides for admission into some class of membership for men of any age and any degree of experience in engineering work. When a young man invests his money, time and energy in the organization of a new engineering society, instead of adding his part to one that has been long established and made a place for itself in the world's work, he is taking the same chance of wasting his talent that he does when he invests in other untried enterprises.

The question of an employment bureau is one worth considering, but it is by no means a new question. Our society and other societies have endeavored in years past to render some service to members on those lines. In the year 1902 the Board of Direction established an engineering directory, the object of which was stated to be "to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members." It adopted rules governing the conduct of this directory, and the bureau appar-

ently was in operation four years. After the year 1905, I find no record in our proceedings of the operation of this employment bureau, but I know that Mr. Warder, who was then secretary of the society, frequently devoted his time and energy to finding openings for members and other engineers who were unemployed. At the present time we have a committee appointed to report on the question of an employment bureau, but apparently the question is not a particularly live one, and though the committee has been in existence more than a year, it has not made any report.

I do not recall that it was ever seriously proposed that our society should maintain a legal department for the benefit of its members, and if it has not been a question of sufficient importance even to be suggested as a part of the society's activities, I doubt whether it is worth while to go into the merits of the question.

This society has at various times had some influence on questions before the legislature or congress. Its activities in this regard seem to have developed in response to a feeling of wide interest in various legislative questions. It is a form of activity which should be promoted only with great caution and after very mature deliberation by the Board of Direction.

IN MEMORIAM

WILLIAM R PATTERSON, M. W. S. E.

Died July 19, 1916.

October, 1916

Mr. William R. Patterson was born at Effingham, New Hampshire, on the 4th day of November, 1854, being the son of David Hubbard Patterson and Irene Rumery Patterson.

He graduated from Dartmouth College in 1876 and became associated with the late Enos M. Barton of the Western Electric Company in 1877.

Mr. Patterson's duties during the earlier years of his connection with the Western Electric Company were of a varied character. He kept all the shop accounts, figuring costs and expense, assisted the bookkeeper in making city collections and handled all of the electrical and chemical problems. It was during his initial year of service that the number of the company's employees reached 100 and the weekly payroll exceeded $1,000.

He was directly responsible for the production of the dry-core telephone cable now so universally used throughout the civilized world and the process of extruding a lead sheath over the cable. He took out nearly 100 patents in connection with the development of these.

He became shop superintendent at Chicago and later general superintendent for the company.

He personally supervised the building of the company's factories and warehouses throughout the United States and in addition thereto planned the rebuilding of branch houses at London, Antwerp and Tokyo.

He was very largely responsible for the layout of the buildings of the company's Hawthorne Works, which have been aptly designated as "the electrical capital of the United States."

He retired from the Western Electric Company on December 31, 1908, after more than thirty years' service and, with Mr. F. E. Davidson, started the firm of Patterson & Davidson, Consulting Engineers, with which firm he continued his relations until his death.

Mr. Patterson was marired to Miss Ida L. Jenks, in Chicago, on the 10th day of October, 1882, and is survived by his wife and three children, William Hubbard, Ida Louise, and Della Irene, to whom we extend our sincere sympathy.

Memoir prepared by O. C. Spurling, F. E. Davidson and Fred J. Postel, Committee.

IN MEMORIAM

JAMES V. ROCKWELL, M. W. S. E.

Died May 24th, 1916.

James V. Rockwell's name stands among the first on the roll of heroes who responded when the slogan "Preparedness" sounded throughout the country. He had reported for duty at the Naval Aeronautic Station, Pensacola, Florida, July 1, 1915, and met his death by drowning, resulting from a falling aeroplane, May 24, 1916.

Mr. Rockwell was born at the home of his grandfather, Dr. V. T. West, at Princeton, Gibson County, Indiana, September 22, 1877. His father, Colonel James Rockwell, of the Ordnance Department, U. S. A., then Lieutenant Rockwell, was stationed at Rock Island Arsenal at the time.

Rockwell's earlier years were spent at different western posts, and his educational opportunities were not of the best. Later, his father was stationed at Watervliet Arsenal, Troy, New York, where the boy attended the Troy Academy, and after graduation there entered the Renssalaer Polytechnic School. While at the Polytechnic he won a competitive examination for appointment to the United States Naval Academy, and passed the entrance examination successfully, but was rejected because of his hearing. He returned to Renssalaer and graduated there in the class of '98. He stood number one in his class, and was highly esteemed for his thoroughness and ability by all of his teachers. In his senior year he left, before the end of the term, to serve in the Spanish-American War, but fortunately was able to get leave to return for his graduation, when he was given the diplomas of all members of his class, absent in war.

His activities in this connection are taken from the records of the U. S. Navy Department, Bureau of Navigation, and are as follows:

"June 22, 1898—Appointed as Assistant Engineer with the rank of Ensign, for temporary service, and assigned to the Bureau of Yards and Docks, serving as Assistant to the Civil Engineer at the Navy Yards at New York City, N. Y., and Norfolk, Va., until February 8, 1899, when he was honorably discharged."

Mr Rockwell became associated with the engineering department of the Chicago and Northwestern Railway Company in March, 1899, and on May 27, 1899, presented his application for Junior Membership in the Western Society of Engineers. He was transferred to Active Membership on application dated November 8, 1902. After serving as rodman and instrumentman, he was appointed assistant engineer in September, 1899, and was in that capacity until July, 1903. During these four years Mr. Rockwell had charge of seven miles of heavy double-track improvement work one season, and twelve miles of the same character of work the next

season in Iowa, after which he was in charge of the construction of eleven miles of new line, five miles of double-track improvement, and other work of similar character in Wisconsin. While he was much interested and liked this class of work, in which he was very efficient and showed much intelligence, he felt it incumbent to follow the wishes of his father and resigned his position, returning to the east to take the examination for the Civil Engineer Corps of the U. S. Navy.

He passed this successfully, and on July 20, 1903, was commissioned an officer of the Navy, as Assistant Civil Engineer. His later activities are transcribed from the records of the Navy Department, Bureau of Navigation:

"September 2, 1903, to March 13, 1905—Detached to the Naval Academy as an Instructor.

"March 13, 1905, to July 25, 1906—Detached, with the rank of Lieutenant, to the Naval Station at San Juan, Porto Rico.

"July 25, 1906, to July 9, 1909—Detached to the Navy Yard, Mare Island, California.

"July 9, 1909, to January 8, 1910—Detached to duty as Inspector of Works, General Electric Company, Schenectady, N. Y.

"January 10, 1910, to March 21, 1911—Detached to the Navy Yard, New York City, N. Y.

"March 21, 1911, to January 3, 1913—Detached to the Navy Yard, Charleston, S. C., as Consulting Engineer and Inspector of Public Works.

"January 3, 1913, to April 10, 1915—Detached on relief to the Bureau of Yards and Docks and on additional duty, Naval Proving Ground, Indian Head, Md.

"April 10, 1915, to May 24, 1916—Detached, with the rank of Lieutenant Commander, to the Navy Yard, New York City, N. Y., and the Naval Aeronautic Station, Pensacola, Fla.

"May 24, 1916—Died this date at Pensacola, Fla., from drowning, resulting from fall in aeroplane, and buried at West Point, N. Y., May 29, 1916."

While on duty in Porto Rico, Mr. Rockwell married Isabel Romero, July 25, 1906, and at his death left three children: James, born 1909; Isabel, born 1911; Carmelita, born 1912. A fourth child, Anita, was born after his death. In addition to his wife and children, he leaves his mother, Eckley West Rockwell; sister, Helen S. Rockwell, and brother, Captain Charles K. Rockwell (formerly U. S. Army Engineers).

Mr. Rockwell was a man of sterling qualities, and all who knew him valued his acquaintance and friendship most highly, finding him kindly, considerate and courteous. His sound, practical and generous judgements were only given after due deliberation and careful study. His friends and associates will long miss his companionship, while his loss to his family cannot be other than irreparable.

Memoir prepared by Hiram J. Slifer, A. A. Schenck and W. J. Towne, Committee.

AMERICAN MINING CONGRESS

Hotel La Salle, Chicago, November 13-16, 1916.

Carl Scholz, president of the American Mining Congress, speaks enthusiastically of the coming convention which opens at Hotel La Salle, Chicago, November 13th. He says:

"The greatest experts in metal, coal and oil have already promised to be here. The Governors of all the states are appointing strong delegations, and it looks as though we would be able to crystallize the sentiment of the entire country on several important issues, notably those of mine-law revision and of added mine safety.

"People generally fail to realize the vast importance of these meetings. Here is where, often, the most important and epoch-making legislation begins. As an illustration, the establishment of the Bureau of Mines was the work of the American Mining Congress. The Federal Trade Commission is in a way the creation of this Congress. While the bill adopted by Congress differed materially from that suggested by us, it had the approval of Mr. Davies, the first chairman. In fact, it was his prediction that every feature in the American Mining Congress measure would eventually be adopted.

"The American Mining Congress is also the inspiration for most of the distinctive coal and metal men organizations of the country. For it was the American Mining Congress that first brought together the producers of coal and metal so that they were able to work to better ultimate results than heretofore. It was our initiative that brought about co-operation in the matter of establishing uniformity of sales terms, uniformity in the preparations for production, and, above all, the adoption of more efficient methods of construction in mining. I do not wish to say that the American Mining Congress claims the credit for all these things. But it was at the meetings of the Congress that the metal and coal men first met, and at these gatherings was born the determination to 'work together,' 'to consult,' 'to co-operate.'

"We intend to have an absolutely fearless discussion of the labor question. Col. George Pope, president of the American Manufacturers' Association, has agreed to discuss the subject from his standpoint, and we will have either Secretary of Labor Wilson, or some one as authoritative, reply. Of course, in many of the states, such as Ohio, Indiana, Illinois, Iowa and Pennsylvania, contracts govern the mine labor situation. But in the far west the situation is very different. In fact, it is the purpose of the Congress to formulate a plan for labor legislation and regulation on which all sides of the controversy can to an extent agree.

"In the matter of 'safety' work there will be some excellent papers read and I look for some illuminating discussion. Right into this discussion I hope to have injected some remarks on the necessity of 'preparedness,' for, after all, in the matter of 'safety' the co-operation of employes is just as essential as safety methods adopted by employers."

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Meeting No. 943, September 25, 1916.

The meeting was called to order at 7:50 p. m. by Chairman DeBerard of the Hydraulic, Sanitary and Municipal Section, with about 40 members and guests present.

President Grant announced that, in compliance with the requirement of the Constitution that vacancies in the offices of the Society shall be filled by the Board of Direction, the Board, at its meeting on September 14th, held an election to fill the vacancy caused by the death of First Vice-President Cartlidge, with the following result:

D. W. Roper, First Vice-President to fill the unexpired term of Mr. Cartlidge.

H. J. Burt, Second Vice-President to fill the unexpired term of Mr. Roper.

Chairman DeBerard then introduced the speaker of the evening, Mr. Clinton B. Stewart, M. W. S. E., who read his paper on "Investigation of Flood Flow of Wisconsin River at Merrill, Wisconsin." The reading of the paper was followed by discussion by Messrs. George E. Ackerman, Ernest McCullough, B. E. Grant, Murray Blanchard, G. W. Stickney and E. N. Layfield. The meeting adjourned about 10:30 p. m.

Meeting No. 944, October 2, 1916.

The meeting was called to order about 8:00 p. m. by First Vice-President Roper, with about 60 members and guests present.

Owing to the unavoidable absence of Prof. Clarence T. Johnston, the author of the paper of the evening, entitled "The Engineer and Public Service," the paper was read by the Secretary. Discussion followed by Messrs. L. K. Sherman, H. J. Burt, W. W. DeBerard, J. W. Lowell, Jr., C. H. Lamb, H. H. Stoek, John Stone, Murray Blanchard, J. L. Jacobs and E. N. Layfield.

The meeting adjourned about 10:00 p. m.

Meeting No. 945, October 9, 1916.

The meeting was called to order at 7:55 p. m. by Chairman Lacher of the Bridge and Structural Section, with about 100 members and guests present.

Mr. Lacher introduced Prof. Wilbur M. Wilson, who read his paper on "Things We Do Not Know About Structural Engineering." Discussion followed by Messrs. Albert Reichmann, H. J. Burt, Ernest McCullough, F. E. Davidson, J. W. Lowell, Jr., H. P. Gillette, F. G. Vent, and Professors Basquin and Newell.

The meeting adjourned about 10:15 p. m.

Meeting No. 946, October 16, 1916.

The meeting was called to order at 8:00 p. m. by Chairman DeBerard of the Hydraulic, Sanitary and Municipal Section, with about 80 members and guests present.

President Grant made an announcement that the officers of the Society had succeeded in making more advantageous arrangements than heretofore for the manufacture of our Society badges, and that they can now be furnished by the Society at the following prices:

Gold badge, with blue enamel, for Members and Associate Members $3.00

Silver badge, with green enamel, for Junior Members and Affiliated Members 2.00

Chairman DeBerard then introduced the speaker of the evening, Mr. Harrison P. Eddy, Consulting Engineer of Boston, who presented his paper on "A Comparison of the Activated Sludge and the Imhoff Tank—Trickling Filter Processes of Sewage Treatment." The paper was discussed by Messrs. J. W. Alvord, Edward Bartow, Langdon Pearse, Paul Rudnick, G. L. Noble, Burton J. Ashley, E. Bahlman, W. S. Shields, Ralph Neufeld, C. B. Burdick and Carl Scholz.

The meeting adjourned about 10:45 p. m.

E. N. Layfield, Secretary.

BOOK REVIEWS

BRIDGE ENGINEERING, By J. A. L. Waddell, C. E., B. A. Sc., Ma. E. D. Sc., D. E., LL. D., Senior Partner of Waddell & Son, Consulting Engineers, Kansas City, Mo. Two volumes, cloth, 6x9 in., illustrated; Vol. I, 1,064 pages; Vol. II, 1,113 pages. Publishers, John Wiley & Sons, Inc., N. Y. Price, $10.00 per set.

Reviewed by Albert Reichmann, M. W. S. E.

This work issued in two volumes covers 80 chapters with a total of 2,177 pages. The list of illustrations covers 304 "Ordinary Figures," 188 "Cross Sections," 68 "Views" and 90 "Tables," making a total of 650 throughout the work, placed with the descriptive reading matter.

Chapter 1 covers the "Evolution of Bridge Engineering"; chapter 2 is devoted to the subject of the "Bridge Specialist"; chapters 3 and 4 cover "Material of Construction" and "Alloy Steels." Six chapters are devoted to loads and forces, such as dead, live, impact, centrifugal, wind and classes of traffic.

Five chapters are devoted to the methods of computation, and allied subjects, such as secondary stresses, deflections, combination of stresses and intensities of working stresses.

Thirteen chapters are devoted to classification and types of structures covering floors, laterals and bracing, plate-girders, I-beams, simple truss bridges, trestle and viaduct, elevated railways, cantilevers, arch, suspension, movable, swing, bascule and vertical lift-bridges.

Six chapters are devoted to the first principles of designing and such allied subjects as detailing in general, shop work and expedients as affecting designing and construction, and general specifications covering super- and sub-structures.

Eight chapters are devoted to special subjects, such as a comparison of riveted versus pin-connected trusses, camber, protection of metal, wooden and reinforced concrete bridges, draw-bridge protection, status of highway bridge building, and bridge failures.

Eight chapters are devoted to foundations covering, general considerations, coffer dams, open dredging, pneumatic process, piles, piers, abutments, walls and culverts, shore protection and boring.

Ten chapters are devoted to such subjects as waterways and War Department requirements, surveys, locations, data, lay-outs, office practice and inspection.

Four chapters are devoted to the subjects of erection and maintenance, including examination and reconstruction work.

Five paragraphs are devoted to such subjects as esthetics and true economy in designing, weights of steel, quantities in masonry and reinforced bridges, and the general subject of estimates.

Ten chapters are devoted to general business features, including specifications in general, contracts, reports, administrations, arbitration, promotion of projects, engineering fees, responsibility, and ethics.

The last and 80th paragraph covers 222 pages on the glossary of terms used in all branches of bridge work.

Unlike most technical treatises and text books, the book is written with a style which holds one's attention and lends great interest to the reading. It gives the reader the sensation of deriving pleasure from his study. This charm in the style is sure to increase the popularity of the work, and make the book more sought for by students of engineering.

This work represents the author's view on the subject of "Bridge Engineering," based on his own large and varied experience, combined with the experiences of a large number of associates in offices, together with the

experiences of other engineers in this field. In a true sense it is not a text-book on the subject, but forms a most valuable adjunct to same. Valuable information can be obtained by any one who has mastered the fundamentals in "Bridge Engineering," no matter whether his actual experience has been limited to a few years, or actually covers a life practice.

The information so generously given by the author was collected during long years of hard labor and at great expense. The average text-book deals only with the scientific side of engineering. The scope of this work is infinite; it discusses the duties of the engineer, the securing of contracts, the proper execution of contracts, the ethics of the engineering profession, correct workmanship, inspection and the business side of engineering; in short, the bulk of the information cannot be found in any other work.

The planning, execution, maintaining and inspecting of a bridge are treated from every conceivable angle and the complete indexing, table of contents, and list of technical terms used, make it easy to find any subject wanted.

In a larger sense this work is a treatise on the subject of "Economics of Bridge Engineering." This train of thought can be traced throughout the entire work, all subjects being treated fully and in a broad way, and with the idea of value constantly brought out.

In his entire work, Dr. Waddell is imbued with one thought which seems paramount to all others—the highest ideals in ethics and engineering are not too high to strive for. Throughout the author's experience, he has always labored to maintain the engineering profession on a high plane, and his latest work will materially aid him in this ambition.

The first view in the first chapter of the work on "Evolution of Bridge Engineering" shows a picture of what the author refers to as being the source of inspiration of the early designers of the suspension type of structure; namely, the so-called "Monkey Bridge." The idea brought out in this picture is, in a way, to be compared with the idea brought out in the much-discussed picture shown in Wellington's work on "Economic Theory of Railroad Location," in which is shown a view of the railway line tunneling through a mountain, with a church steeple shown in the valley, indicating the proximity of a town. Wellington did not produce this picture with the idea of it serving as an inspiration as to how to economically locate the railway line, but offered same to show how not to build, leaving also some food for thought to the ingenuity of the reader. The work of Waddell is treated along the same lines that Wellington handled his subject, and, therefore, Waddell's work should be looked upon as a treatise on economics.

The second chapter on the "Bridge Specialist" gives the author's idea, in a well presented manner, of the importance of entrusting to a man who has had special training in order to economically handle the subject of "Construction in Bridge Work."

Emphasis is placed upon the importance of correct details in bridge designing, rather than upon the main members. This principle is recognized by all designers of experience, but the incidents recited from the author's practice illustrating the non-observance of this principle cannot fail to be interesting and instructive.

The chapter on alloy steels is comprehensive and up-to-date, and contains a fund of valuable information on the various steels, such as nickel, high carbon, mayari steel, silicon steel, as well as other alloys.

The four paragraphs on "Movable Bridges" are general in scope, the author stating that at some future date this subject will be handled in an exhaustive and detailed monograph by Mr. Harrington, a former partner of the author.

These two volumes will prove an invaluable aid to any one in the field of "Bridge Engineering." No matter what the experience may have been of other engineers, they are bound to benefit, no matter whether they examine it for an occasional interesting hour's review on any particular subject that they may be interested in, or whether they take up the work with the idea of a detailed study in its entire form.

Journal of the
Western Society of Engineers

Vol. XXI. NOVEMBER, 1916 No. 9

INVESTIGATION OF FLOOD FLOW ON THE WISCONSIN RIVER AT MERRILL, WISCONSIN, JULY 23-24, 1912

By Clinton B. Stewart, M. W. S. E.

Presented September 25, 1916.

Outline: This investigation was made in connection with a lawsuit, resulting from the failure of the Merrill Railway and Lighting Company's dam, located at Merrill, Wisconsin, the owners alleging that failure was due to a break in the Merrill Boom Company's dam, which is located about 2½ miles up-stream from Merrill.

The investigation includes a study of the rainfall of 11.25 inches in 24 hours, which caused the flood, the determination of the resulting flood flow of about 96 second feet per square mile from 450 square miles of drainage area, covered by the heavier portion of the rainfall; a determination of the flood flow coefficient "*C*" in the Chezy formula, varying from about 40 to 70, and of the coefficient "*n*" in the Kütter formula, varying from a value 0.03 in unobstructed reaches of the river to about 0.07 in reaches where islands were overflowed; a study of the flow over broad crest submerged dams, showing that when the dam is 90% submerged the coefficient of discharge "*C*" in the formula $Q = Clh^{3/2}$ is about 90% of the coefficient of discharge when unsubmerged; and, finally the determination of the increase of flood flow resulting from the break in the submerged dam belonging to the Merrill Boom Company, and of the extent which this contributed to the failure of the Merrill Railway & Lighting Company's Dam.

The Merrill Railway and Lighting Company's dam was a timber crib dam, with Tainter gates and sluice gates, aggregating about 495 feet in width. The pond formed by the dam has an area of about 374 acres at high water. Failure during the flood of July 23-24th resulted from water overflowing one of the dykes as shown by the photograph (Fig 1.).

The Merrill Boom Company's dam was a timber crib dam with sluice gates aggregating 234 feet in width and spillways aggregating about 530 feet in width. The pond formed by the dam has an area of about 292 acres at high water. During normal stage of river the dam held up a head of about 5 feet, while during flood stage both

the sluice gates and spillway became submerged. At some unknown time during the night of July 23-24th, a portion of the spillway, 105 feet in length, was washed out and released water from the pond of the Merrill Boom Company's dam onto the pond of the Merrill Railway and Lighting Company's dam. The increase in elevation of the pond of the Merrill Railway and Lighting Company's dam resulting from the break, thus became one of the factors to be determined, and in connection with a curve showing the relation of elevation of pond to discharge, furnished the means of determining the effect of the break on flood flow.

Figure 2 is a map showing the Wisconsin River in the vicinity of Merrill, the location of the two dams and hydraulic data pertaining to the various cross sections which were taken.

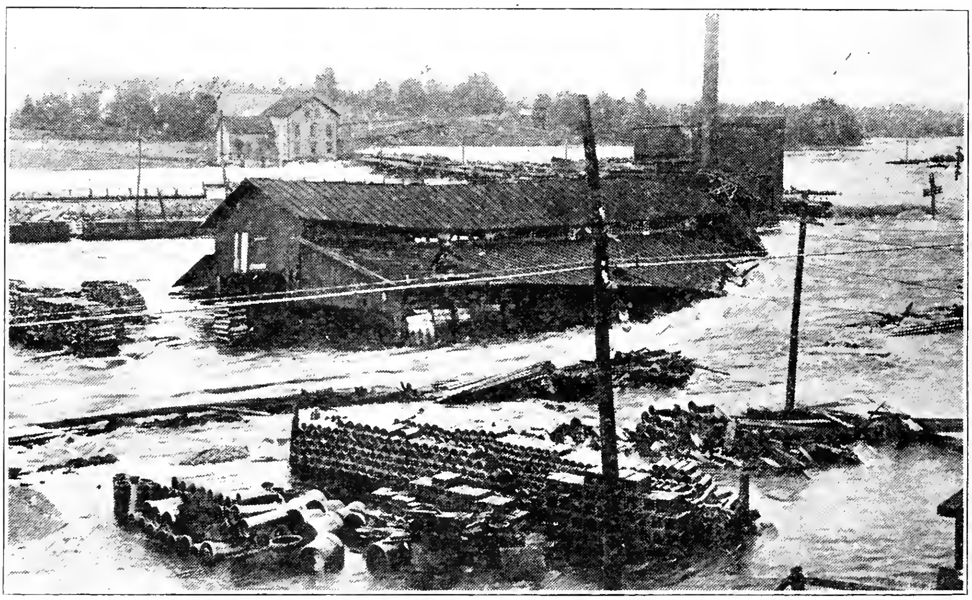


Fig. 1—Flood at Merrill, Wis., July 24, 1912. Water Washing Around the Dam.

Study of Rainfall Conditions.—The character of the rainfall which caused the flood is shown on Fig. 3 by means of contours. In all cases the amounts of rainfall indicated fell in a period of about 24 hours. The center of the storm was apparently at or about Merrill, 11.25 inches having fallen in 24 hours. The contour curves show that about 10 inches and over of rainfall, in a 24-hour period, covered about 100 square miles, while 6 inches and over covered about 1,650 square miles.

In the ten-day period culminating with the storm, 12.05 inches of rainfall occurred, while in the 30-day period culminating with the storm, 14.64 inches of rainfall occurred.*

*For comparison between this storm and other storms that have occurred in Wisconsin, Illinois and Iowa, see paper by the writer in Journal of the Western Society of Engineers, April, 1913.

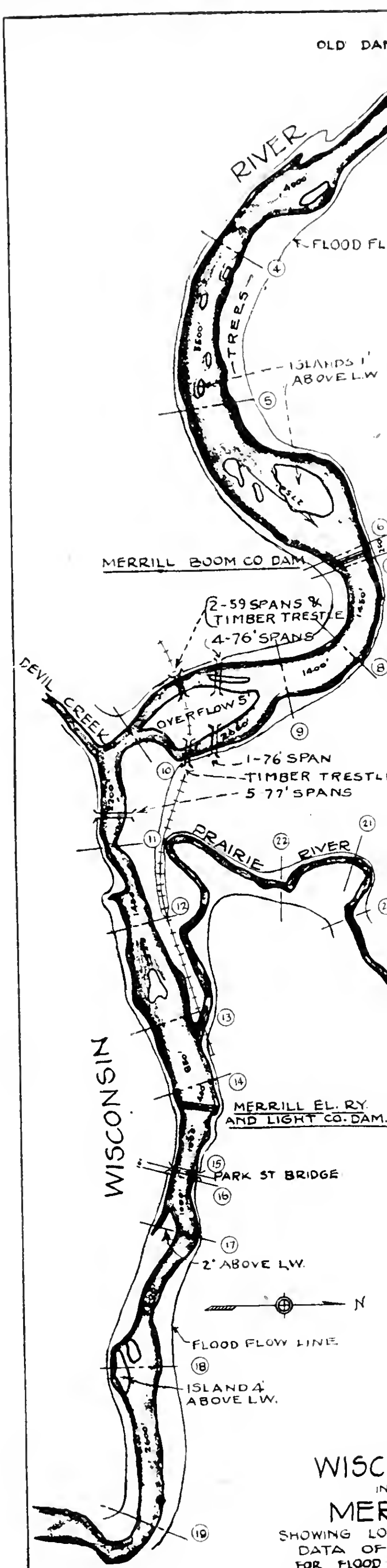


TABLE OF
HYDRAULIC DATA OF CROSS SECTIONS.
WISCONSIN RIVER

SEC. LOCATION	NO.		ELEV	DATE	GAGE	WIDTH	AREA	WETTED P.	"r"
STA 284	1	A	1269.08	7/24	17.5	2 280	20 300	2 285	8.80
		B	56 39	10/23	4.7	350	1 040	352	2.96
200' ABOVE OLD DAM #2	2		66 84	7/24	17.5	790	7 640	794	9.66
			55.02	10/23	4.7	400	1 330	402	3.33
100' BELOW OLD DAM #2	3		66.84	7/24	17.5	445	6760	447	15.20
			54 39	10/23	4.7	300	1 740	362	4.84
"IK"	4		64.35	7/24	17.5	1275	10 330	1277	8.14
			53.31	10/23	4.7	520	1 230	525	2.35
"LM"	5		62.25	7/24	17.5	1250	10 820	1252	8.70
			51 39	10/21	5.0	400	910	402	2.29
150' ABOVE MB Co DAM	6		61 40	7/24	17.5	1335	12 820	1340	9.62
			50 52	10/21	5.0	600	1 700	608	2.81
100' BELOW MB Co DAM	7		60 46	7/24	17.5	1055	11 800	1060	11.20
			49 68	10/21	5.0	430	3420	437	7.86
"PR"	8		60 14	7/24	17.5	900	8 390	906	9.31
			49.36	10/21	5.0	445	2 240	450	5.03
STA 545	9		59 88	7/24	17.5	1 330	12 060	1 333	9.08
			49 89	10/23	4.7	585	2 870	588	4.90
STA 573	10		58.92	7/24	17.5	1 320	11 400	1 324	8.65
			49 80	10/23	4.7	515	3 500	519	6.77
STA. 594+	11		57.91	7/24	17.5	1125	7 420	1131	6.60
			49 78	10/23	4.7	310	2 120	312	6.85
STA 37	12		56 91	7/24	17.5	980	7 570	983	7.75
			49 72	10/23	4.7	380	3130	382	8.20
STA 629	13		55.44	7/24	17.5	1010	10 150	1016	10.05
			49.63	10/23	4.7	750	4 930	754	6.54
STA 638	14		54.94	7/24	17.5	850	9 050	864	10.64
			49 64	10/23	4.7	740	5490	743	7.42
AT PARK ST. BRIDGE	15	A	47 12	7/24	17.5	341	5242	384	13.30
			42.12		12.5	337	3545	363	9.40
			38.62		9.0	334	2372	349	6.41
		B	35.42	10/31	5.8	317	1522	320	3.71
100' BELOW PARK ST BRIDGE	16		47.12	7/24	17.5	470	6150	473	13.09
			42 12		12.5	420	3920	429	9.17
			38.62		9.0	390	2530	391	6.54
			34 82	10/31	5.2	350	1 200	351	3.46
1100' BELOW PARK ST BRIDGE	17		46.71	7/24	17.5	670	8 860	679	13.11
			41 58		12.5	645	5590	651	8.62
			38.00		9.0	630	3 385	631	5.40
			34.10	10/31	5.2	380	930	385	2.44
3400' BELOW PARK ST BRIDGE	18		45.60	7/24	17.5	1 190	11 970	1199	10.01
			40.30		12.5	1 110	6 250	1117	5.62
			36.75		9.0	480	3390	490	6.94
			32 80	10/31	5.2	430	1 050	437	2.42
6000' BELOW PARK ST BRIDGE	19		43 00	7/24	17.5	830	8 250	837	9.92
			38 12		12.5	640	4 710	649	7.30
			34.70		9.0	475	2 870	481	6.00
			31.00	10/31	5.2	400	1 450	406	3.59
PRAIRIE RIVER.									
N END BLAINE ST TO S END MONROE ST	20		63.80	7/24	17.5	1006	6750	1014	6.65
			54.30	10/18	5.6	110	200	112	1.79
COR LOGAN & 5TH TO COR JEFFERSON & 8TH	21		61.95	7/24	17.5	1 566	10660	1 576	6.76
			52.50	10/18	5.6	70	110	72	1.53
OPP. CENTER OF BLQ WILLARD'S ADD'N	22		59.70	7/24	17.5	510	3080	514	6.00
			50.79	10/18	5.6	90	160	92	1.74

NOTE: STA NUMBERS & LETTERS REFER TO NEWMAN'S SURVEY 1888.
GAGE R'D'GS AT PARK ST. BRIDGE.
ELEV. ABOVE SEA LEVEL.
A - H.W. FLOW JULY 24, 1912.
B - L.W. DATE GIVEN, 1913.

FIG. 2

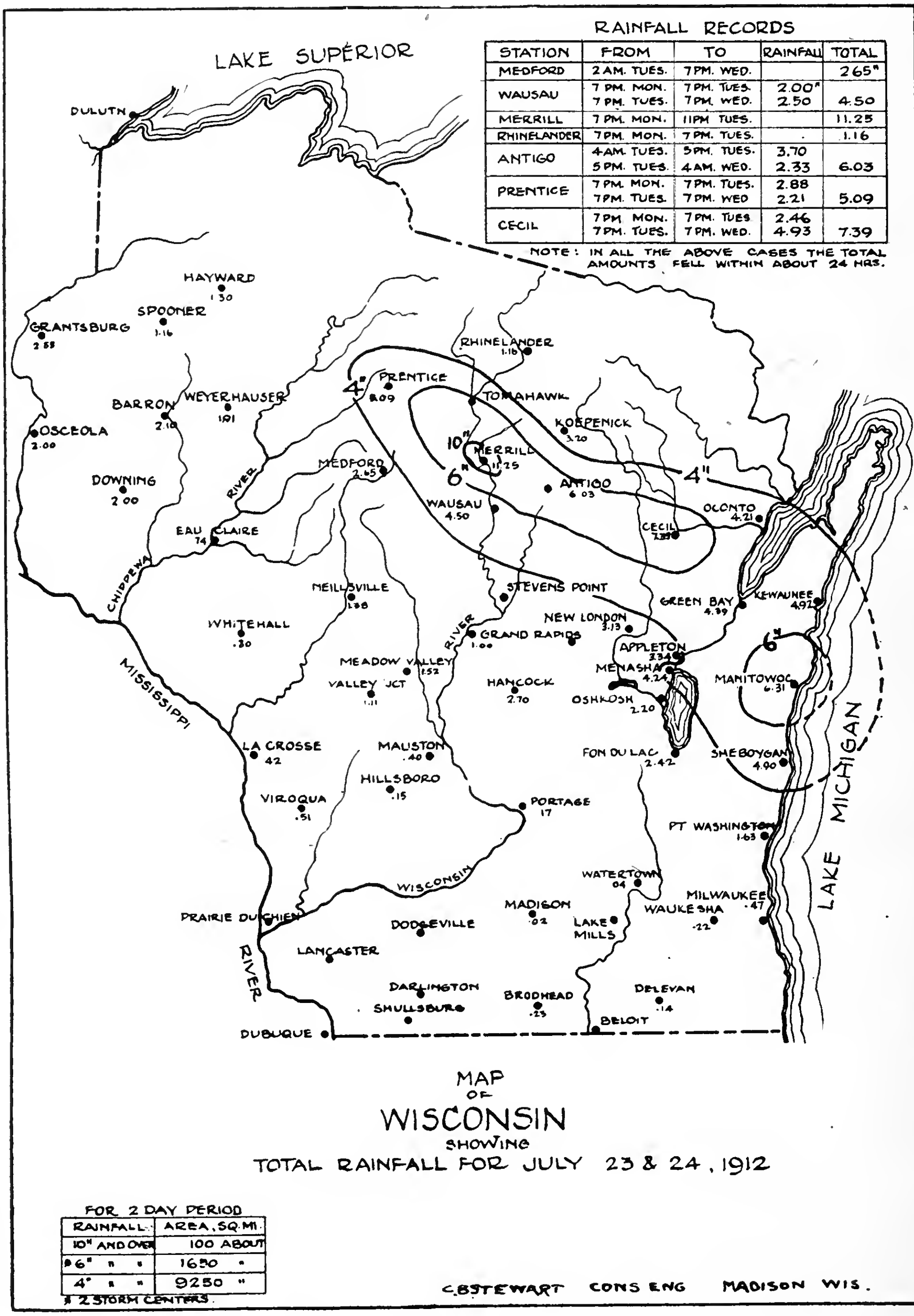

RAINFALL RECORDS
STATION | FROM | TO | RAINFALL | TOTAL
MEDFORD | 2 AM. TUES. | 7 PM. WED. | | 2.65"
WAUSAU | 7 PM. MON. / 7 PM. TUES. | 7 PM. TUES. / 7 PM. WED. | 2.00" / 2.50 | 4.50
MERRILL | 7 PM. MON. | 11 PM TUES. | | 11.25
RHINELANDER | 7 PM. MON. | 7 PM. TUES. | | 1.16
ANTIGO | 4 AM. TUES. / 5 PM. TUES. | 5 PM. TUES. / 4 AM. WED. | 3.70 / 2.33 | 6.03
PRENTICE | 7 PM. MON. / 7 PM. TUES. | 7 PM. TUES. / 7 PM. WED | 2.88 / 2.21 | 5.09
CECIL | 7 PM MON. / 7 PM. TUES. | 7 PM. TUES / 7 PM. WED. | 2.46 / 4.93 | 7.39
NOTE: IN ALL THE ABOVE CASES THE TOTAL AMOUNTS FELL WITHIN ABOUT 24 HRS.
LAKE SUPERIOR
DULUTH
HAYWARD 1.30
SPOONER 1.16
GRANTSBURG 2.53
BARRON 2.10
WEYERHAUSER 1.91
OSCEOLA 2.00
DOWNING 2.00
EAU CLAIRE .74
CHIPPEWA RIVER
RHINELANDER 1.16
PRENTICE 5.09
TOMAHAWK
MERRILL 11.25
KOEPENICK 3.20
MEDFORD 2.65
ANTIGO 6.03
WAUSAU 4.50
OCONTO 4.21
CECIL 7.39
NEILLSVILLE 1.38
STEVENS POINT
GREEN BAY 4.39
KEWAUNEE 4.92
WHITEHALL .30
NEW LONDON 3.13
GRAND RAPIDS 1.00
APPLETON 3.34
MEADOW VALLEY 1.52
VALLEY JCT 1.11
MENASHA 4.24
HANCOCK 2.70
OSHKOSH 2.20
MANITOWOC 6.31
MISSISSIPPI
LA CROSSE .42
MAUSTON .40
FON DU LAC 2.42
SHEBOYGAN 4.90
HILLSBORO .15
VIROQUA .51
PORTAGE .17
PT WASHINGTON 1.63
WATERTOWN .04
MILWAUKEE .47
WAUKESHA .22
MADISON .02
LAKE MILLS
PRAIRIE DU CHIEN
DODGEVILLE
LANCASTER
WISCONSIN RIVER
DARLINGTON
SHULLSBURG
BRODHEAD .23
DELEVAN .14
BELOIT
DUBUQUE
LAKE MICHIGAN
4"
6"
10"
MAP OF WISCONSIN SHOWING TOTAL RAINFALL FOR JULY 23 & 24, 1912
FOR 2 DAY PERIOD
RAINFALL | AREA, SQ. MI.
10" AND OVER | 100 ABOUT
*6" " " | 1650 "
4" " " | 9250 "
* 2 STORM CENTERS.
C. B. STEWART CONS ENG MADISON WIS.

Fig. 3.

Figure 4 is a sketch showing the drainage area of the Wisconsin River between Tomahawk and Merrill, and the rainfall contours for the storm of July 23rd and 24th, 1912. The total drainage area of

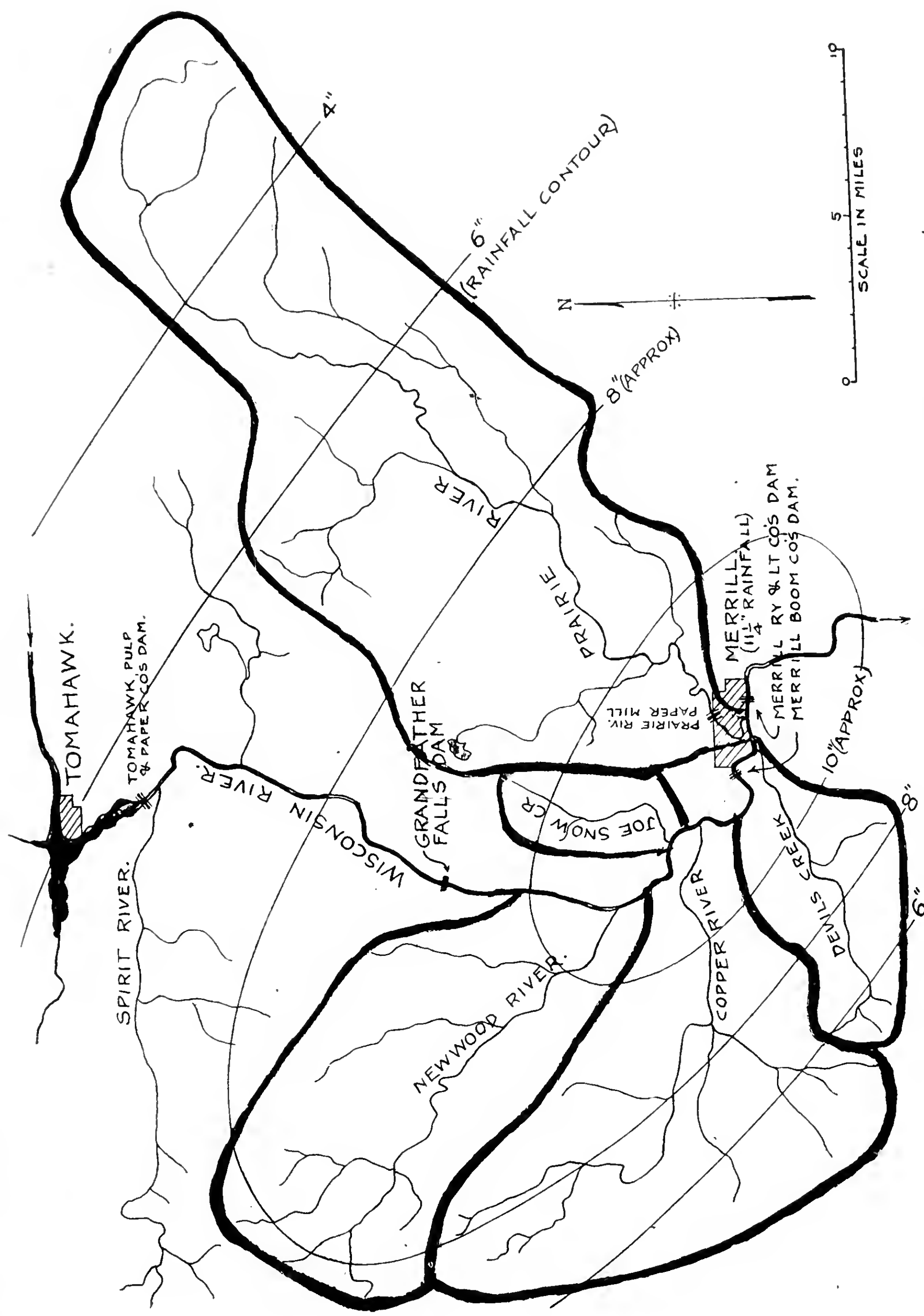


Fig 4-Sketch of Drainage Area of Wisconsin River, between Tomahawk and Merrill and Rainfall contours for storm of July 23-24, 1912.

the Wisconsin River above Merrill is about 2,600 square miles, while between Tomahawk and Merrill the drainage area is about 700

square miles, and between Grandfather Falls and Merrill about 450 square miles.

The main contribution to the flood flow came from the tributaries entering the Wisconsin River between Grandfather Falls and Merrill. The average rainfall over the 450 square miles between these points amounted to about 8 inches.

Character of Soil and Topography.—The topography of the Wisconsin River's watershed above Tomahawk is quite level, with inland lakes and marshes, many of which are used for storage reservoirs. The soil consists of glacial drift of almost pure sand.

In the reach from Tomahawk to Merrill the slope of the river valley increases and equals about 6½ feet per mile. The fall of the river is mostly concentrated at several points, however, leaving the effective slope of the river for stream flow about 1.3 feet per mile.

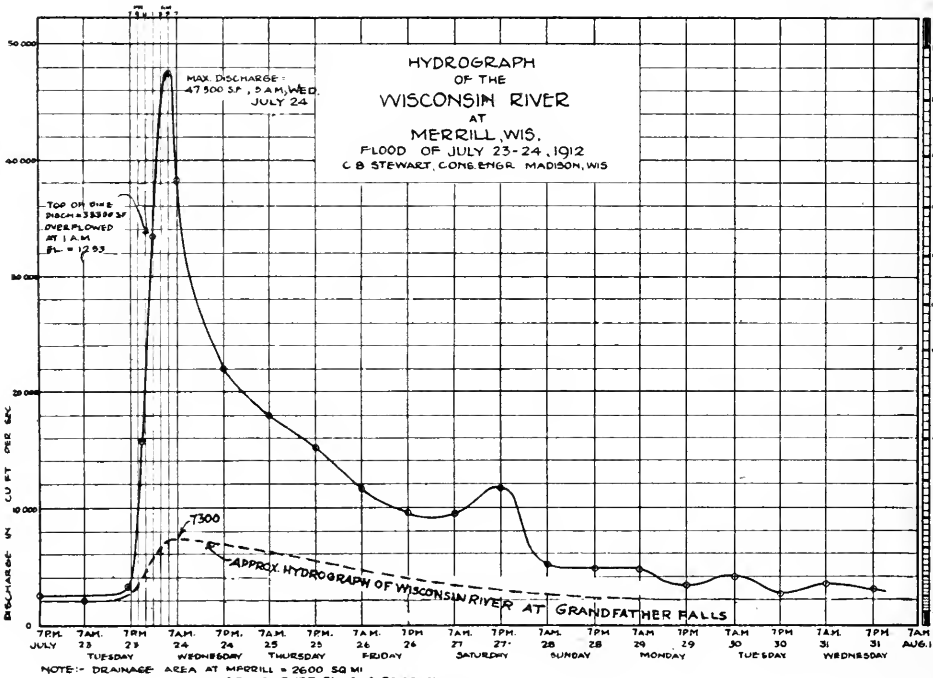


Fig. 5.

Below Grandfather Falls the tributaries of the main river have quite steep slopes, that of the stream beds varying from about 10 to 30 feet per mile, while the side slopes of the tributaries in cases vary from about 50 to 100 feet per mile. The soil on these tributaries and in the vicinity of Merrill consists of sand loam mixed with gravel and clay.

Hydrograph of the Wisconsin River at Merrill, Wisconsin, During the Flood.—Figure 5 is a hydrograph of the Wisconsin River at Merrill during the flood of July 23-24th, 1912, and continuing until July 31st. This hydrograph was platted by means of the discharge curve of the river at Park Street bridge in Merrill, as shown on Figure 6. The discharge curve is based on records of stream flow of

the Wisconsin River by the U. S. Geological Survey from 1902-1907, and a measurement by the writer during 1910. The curve is well defined up to a gage reading of about 9 feet. Above this point the curve is approximate, but the general direction is quite well defined. As drawn, the curve agrees with an observed gage reading of 12.5 feet for a previous flood flow of 25,500 second feet on October 6, 1911, as computed by the writer from the depths in the sluice gates of the Merrill Railway and Lighting Company's dam during the flood.

The maximum gage reading during the flood of July 23-24th, 1912, was 17.5 feet at 5 a. m. July 24th, and the discharge corresponding to this is seen to amount to 47,500 second feet.

The flow of the Wisconsin River at Grandfather Falls, during

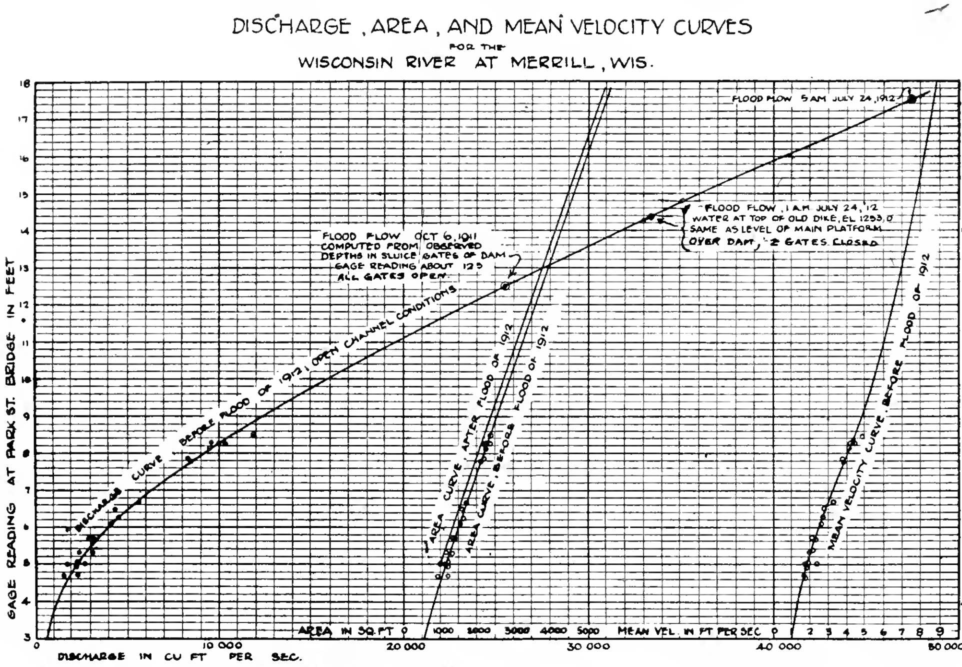


Fig. 6.

the flood, has been obtained from the gate openings and power developed at the water power plant at this place. The results are shown on Fig. 5 in the form of a hydrograph.

Allowing 4,500 second feet for the contribution to flood flow from Grandfather Falls (as shown later), the maximum rate of flood flow from the 450 square miles of drainage area, between Grandfather Falls and Merrill, would amount to 43,000 second feet. This would be equivalent to 96 second feet per square mile of drainage area. For the entire drainage area of 2,600 square miles above Merrill the maximum rate of flood flow was about 18.3 second feet per square mile.

The daily run-off at Merrill and Grandfather Falls resulting from the storm of July 23-24th, is shown in the following table, to-

gether with the daily and accumulated run-off from the 450 square miles of drainage area between these two points.

DAILY AND ACCUMULATED RUN OFF
FROM
450 SQ MILES OF WATERSHED, GRANDFATHER FALLS-MERRILL
RESULTING FROM
AVERAGE RAINFALL OF 8" IN 24 HOURS, JULY 23-24 1912

TIME PERIOD	RUN-OFF AT MERRILL BILLION CU FT	RUN-OFF AT GRANDFATHER FALLS BILL CU FT	NET RUN-OFF FROM 450 SQ MI BILL. CU FT.	INCHES RUN-OFF FROM 450 SQ MI	ACCUMULATED RUN-OFF INCHES DEPTH	PERCENTAGE OF 8" RAINFALL APPEARING AS RUN-OFF.
7P.M 23-7P.M, 24	2 53	0 56	1.97	1.91	1.91	24
" 24 - 25	1 57	0 53	1 04	1 01	2.92	36
" 25 - " 26.	1 02	0 41	0 61	0 59	3 51	44
" 26 - " 27.	0 86	0 30	0 56	0 54	4.05	50
" 27 - " 28.	0 57	0 22	0 35	0 34	4 39	55
" 28 - " 29	0 38	0 18	0 20	0 19	4.58	57
" 29 - " 30.	0 30	0 18	0.12	0 12	4.70	59
TOTAL	7 23	2 38	4 85	4.70		

It will be noted that during the first day about 1.91 inches or 24% of the average rainfall of 8 inches appeared as run-off, while in the entire seven days about 4.7 inches, or about 60% of rainfall appeared as run-off.

Discharge Curve Merrill Railway & Lighting Company's Dam.—The elevation of the pond of the Merrill Railway & Lighting Company's dam, corresponding to the discharge of 47,500 second feet was about 1,254.9 feet (See Fig. 7). The statement of the gate

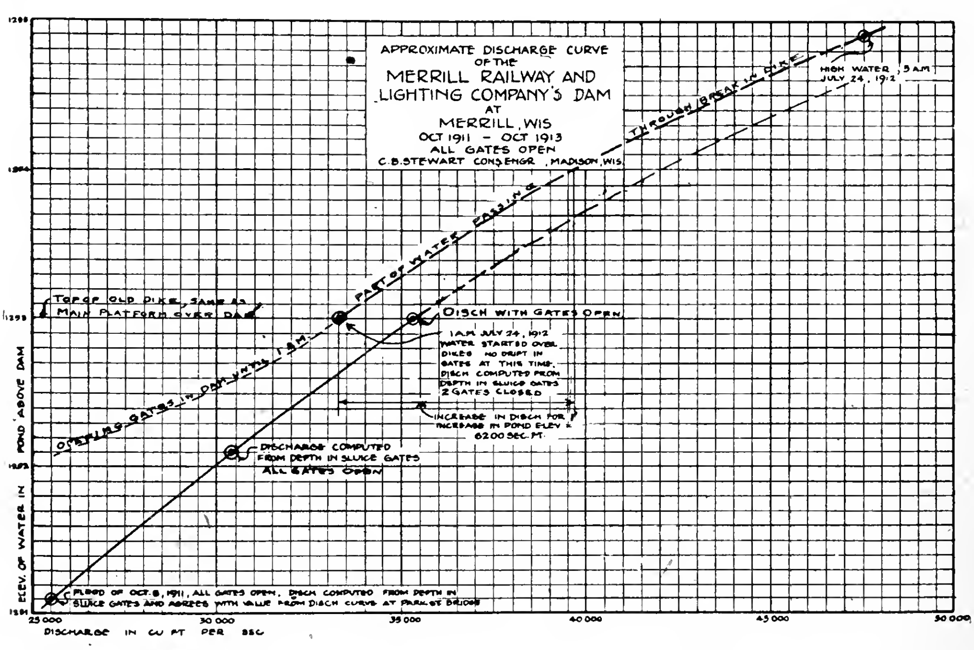


Fig. 7.

tender of the Merrill Railway & Light Company's dam seems to show that at "1 a. m., July 24th, all of the gates of the dam were open except two," one being a lift gate, 15½ feet wide and 10 feet deep, capacity 1,400 second feet, and one a needle gate, capacity 600 second feet, that "the gates were free from drift, and that at about this time the water was just starting over the dyke near the lighting plant." The elevation of the top of this dyke is about 1,253.0 feet, about the same as the elevation of the main floor over the dam. Computations of the flow through the sluice gates of the dam with all gates open, and with an elevation of the pond, 1,253.0 feet, show a discharge of 35,300 second feet. The discharge at 1 a. m., July 24th, was less than 35,300 second feet by the capacity of the two gates which remained closed, or 2,000 second feet, amounting, therefore, to 33,300 second feet. The elevation of the pond during the flood of October 6th, 1911, was 1,251.1 feet, and the corresponding discharge as noted, was 25,500 second feet. For elevation of 1,251.1 feet, the corresponding discharge would amount to 30,400 second feet. Figure 7 shows the discharge curve of the dam from the computations noted, with two gates closed. Subsequent to the break in the dyke at about 1 a. m., there may have been drift in the sluice gates of the dam. The portion of the discharge curve above elevation 1,253.0 feet, is, therefore, drawn to pass through the two points of discharge corresponding to 33,300 at 1 a. m., and through the discharge of 47,500 for high water at 5 a. m. The curve thus represents conditions as they existed of relation of discharge to elevation of pond. The same law of relation of discharge to elevation of pond practically continued above elevation 1,253.0 feet, so that if there had been no break in the dyke and all the gates had remained open and free from drift, the water in the pond would have risen to an elevation of about 1,254.6 feet. The discharge curve indicates that for an increase of elevation of pond from 1,253.0 feet to 1,254.0 feet, there was an increase in discharge of 6,200 second feet.

Flood Flow of the Wisconsin River at the Merrill Boom Company's Dam.—The Merrill Boom Company's dam is located on the Wisconsin River about 2.4 miles above the Merrill Railway & Lighting Company's dam. Between these two dams the Prairie River and Devil's Creek enter the Wisconsin River. Above the Merrill Boom Company's dam, the Copper River, Joe Snow Creek and Newwood River enter the Wisconsin River at the respective distances of about 5, 6 and 9 miles above the Merrill Railway & Lighting Company's dam. Table No. 1 gives information as to the watersheds of these streams, together with an estimate of the flood flow contributed from each stream to the flood flow of the Wisconsin River at the Merrill Railway & Lighting Company's dam at about 1 a. m. and 5 a. m., July 24th, 1912.

In making this estimate, the character of each water-shed as regards slope and soil condition, was investigated in the field and given careful consideration. The location of its water-shed, as regards lying entirely or only partially within the heavy rainfall

district, was also considered. This was the case with the Prairie River, the rainfall at its headquarters being less than in the vicinity of Merrill.

Experience shows that the flood flow per square mile, for small water-sheds is larger than for large water-sheds. This follows from the fact that on the large water-shed a longer period of time is required for the effect of rainfall to reach its outlet. The best evidence available indicates that with similar soil condition, slope, form of watershed and rainfall, the flood flow will vary about as the 4/5 power of the area of the water-shed.

The water-sheds outlined in Table No. 1 include all of the water-sheds of the Wisconsin River between the Merrill Railway & Lighting Company's dam and Grandfather Falls. The contribution to the flow of the river at the Merrill Railway & Lighting Company's dam at 1 a. m. and 5 a. m., July 24th, from Grandfather Falls, has been taken as equal to the flow at Grandfather Falls at 8 p. m. and 12 p. m. of July 23rd, thus allowing 5 hours for passing of the flood crest over the 14 miles between the two points.

TABLE No. 1.

APPROXIMATE FLOOD FLOW FROM STREAMS ENTERING THE WISCONSIN RIVER BETWEEN THE MERRILL RAILWAY AND LIGHTING CO.'S DAM AND GRANDFATHER FALLS.

July 24, 1912.

Stream	Drainage Area	Mouth Above Lt. Co. Dam	Length of Watershed	Dist. From Center of Watershed to L. Co. Dam	Est. Time to Deliver Max. Flow at Lt. Co. Dam "a"	Est. of Max. Flood Flow Sec. Ft. per	Approximate Contribution to Flood Flow at Lt. Co. Dam about 1 a. m.	about 5 a. m.
	Sq. Mi.	Mi.	Mi.	Mi.	Hrs.	Sq. Mi.	Sec. Ft.	Sec. Ft.
Devil's Creek	30	1	9	5½	2	200 at 1 a. m.	6,000	2,000
Copper River	88	5	17	13½	5	125 at 5 a. m.	7,000	11,000
Joe Snow Creek	23	6	5	8½	3½	175 at 1 a. m.	4,000	1,000
Newwood River	87	9	16	17	7	125 at 5 a. m.	6,700	10,900
Prairie River to Paper Mill Dam	214	¼	29	15	6	65 at 5 a. m.	5,000	14,000
Vicinity of Merrill below Boom Co.'s Dam	6	¼	..	..	1	300 at 1 a. m.	1,800	300
Contributed to flow from Grandfather Falls	..	..	..	14	5½	....	2,600	4,500
Contributed from Prairie Pond by break in Dam	..	..	..	..	..	....	....	3,800
Totals	448						33,100	47,500
Passing through Merrill Boom Co.'s Dam							20,300	27,400

"a" Time of delivery based on velocity of flow of flood crest at 2½ miles per hour.

From the hydrograph of the Wisconsin River at Grandfather

Falls, during the flood, as shown on Fig. 5 it will be noted that the maximum flow was about 7,300 second feet at about 7:00 a. m., July 24th. The flow at 8:00 p. m., July 23rd, was about 2,600 second feet and would reach the Merrill Railway & Lighting Company's dam at about 1:00 a. m., while the flow at 12:00 p. m. was about 4,500 second feet, and would reach the Merrill Railway & Lighting Company's dam at about 5:00 a. m.

The total flood flow at the Merrill Railway & Lighting Company's dam at 1:00 a. m. is seen to amount to 33,100 second feet, this being the same as the gate capacity of the dam with a pond elevation of 1,253.0 feet, with two gates previously mentioned closed. The

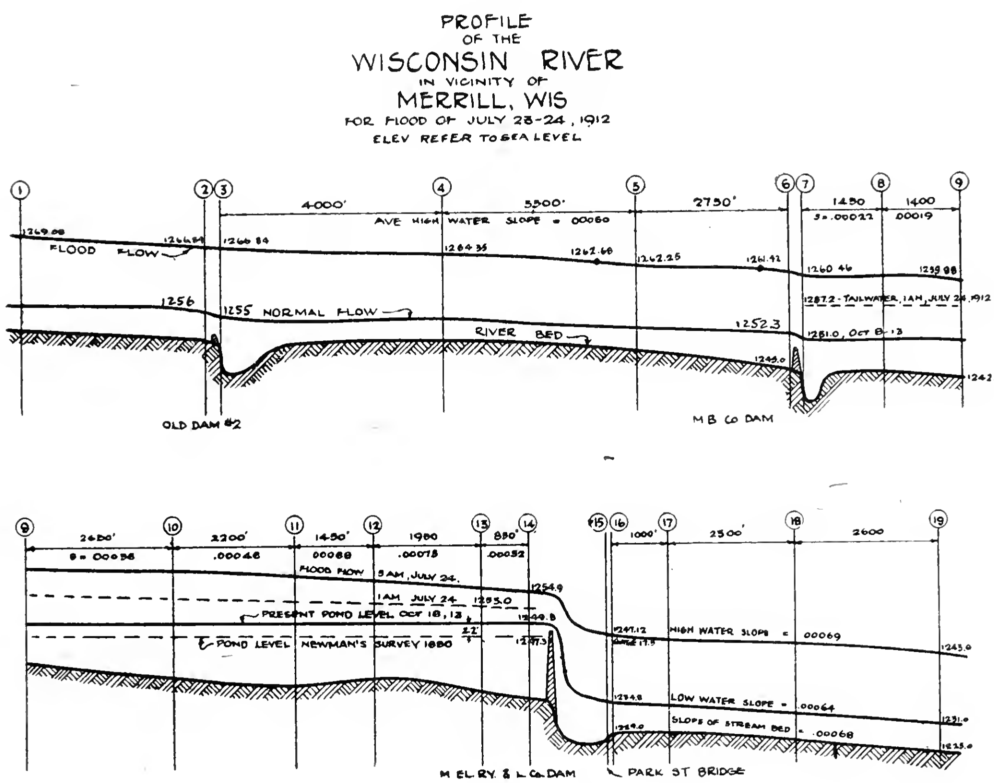


Fig. 8.

portion of the flow passing over the Merrill Boom Company's dam is assumed as 20,300 second feet.

The total flow at 5:00 a. m. at the Merrill Railway & Lighting Company's dam is seen to amount to 47,500 second feet, while the portion that passed over the Merrill Boom Company's dam was 27,400 second feet.

Computation of Flood Flow From Flood Cross Sections and River Slopes.—In order to determine if there was any backwater effect on the gage reading of 17.5 feet at the Park Street bridge at 5:00 a. m., July 24th, and also to check approximately the assumed distribution of flood flow that was made, a considerable number of flood cross sections of the river were measured, and the slope of the

flood plane between the various cross sections determined as closely as possible. Figure 2 shows the hydraulic data pertaining to flood flow and also normal low water flow, collected in tabular form. Figure 8 shows a profile of the high water during the flood and also of normal low water. Referring to Fig. 8, it will be noted that the slope of the water surface below Park Street bridge for high water is greater than the slope of the water surface for normal low water. This is in accordance with the usual conditions of relation of flood flow to slope on rivers, that as the stage of the river increases the slope on long flat reaches increases, while the slope at the rapids decreases.

Table No. 2 shows the results of computations for the flood flow co-efficients for the various reaches of the river for the assumed distribution of flow from the different portions of the drainage area. It will be seen that the average value of the co-efficient C in the Chezy formula for average velocity, $V = C\sqrt{rs}$ varies from 34 to about 70, with an average value of about 60. Below the Park Street bridge the value of C has been determined for four stages of the river from low water to extreme high water. The values of C in each reach from low water to flood stage is seen to be quite consistent, such changes as occur being easily accounted for by obstructions to flow by islands or the spreading out of the river and the general shape of the cross sections. The method of computation of flood flow from flood cross sections and river slopes is necessarily approximate on rivers with changing cross sections and obstructions to flow. The writer believes that the results of the computations show that the flood flows assumed are substantially correct.

Computation of Flood Flow Over the Merrill Boom Company's Dam.—The high water marks above and below the Merrill Boom Company's dam indicate that the dam was very nearly submerged. At Oloff's Mill, about 1,100 feet above the dam, the high water mark was 1,261.42 feet, indicating an elevation of about 1,261.0 feet just above the dam. Below the dam the high water marks indicate an elevation of about 1,260.5 feet. This would make a difference of water level of 0.5 feet. In the computation of the flow through the sluice gates and over the spillway of the dam, it is necessary to consider the effect of the velocity of approach of the water to the openings. The experimental coefficient C for the discharge for weirs, $Q = ClH^{3/2}$ is usually for discharge from quiet water, H being equal to the observed head plus a correction for velocity of approach, and l the length of the weir. The correction for velocity of approach is usually taken as 1 1/3 times the head, $\frac{V^2}{2g}$, due to the average velocity in the channel leading to the weir. The average velocity in the entire cross section of the river above the Merrill Boom Company's dam averaged about 2½ feet per second, while in the main channel of the stream above the dam it is probable that the average velocity in a vertical plane was about 5 or 6 feet per second. The

amount to allow as correction for velocity of approach cannot be determined definitely. The value, 0.7 feet, has been taken as a rea-

TABLE NO. 2
SHOWING
COMPUTATIONS FOR FLOOD FLOW COEFFICIENTS
FOR
ASSUMED DISCHARGES WITH GIVEN FLOOD FLOW CROSS-SECTIONS AND RIVER SLOPES

LOCATION OF SECTION	ELEV	AREA	HYDRAULIC RADIUS r	AVE AREA	AVE RADIUS	LENGTH OF REACH	ASSUMED DISCHARGE	AVE VELOCITY V	SLOPE OF WATER SURF.	* COEFF C.	† COEFF n.	REMARKS
						ABOVE MERRILL BOOM COMPANY'S DAM						
3	1266.84	6760	15.20									
				8545	11.67	4000	27 000	3.20	.00050	42	.060	1 ISLAND & TREES.
4	64.36	10 330	8.14									
				10 575	8.42	3500	27 000	2.56	.00050	40	.059	4 " " "
5	62.25	10 820	8.70									
				11 820	9.16	2750	27 000	2.28	.00050	34	.072	3 " " "
6	61.40	12 820	9.62									
						BETWEEN MERRILL B. CO DAM AND MERRILL RY. & LT. CO. DAM						
7	60.46	11 800	11.20									
				10 095	10.25	1450	27 000	2.67	.00022	56	.043	
8	60.14	8390	9.31									
				10 225	9.20	1400	27 000	2.65	.00019	63	.037	
9	59.88	12 060	9.08									
				11 730	8.86	2650	27 000	2.31	.00036	41	.058	2 ISLANDS & BRIDGES
10	58.92	11 400	8.65									
				9410	7.63	2200	29000	3.08	.00046	52	.045	BRIDGE
11	57.91	7420	6.60									
				7495	7.18	1450	29000	3.88	.00068	56	.043	
12	56.91	7570	7.75									
				8860	8.90	1950	29000	3.28	.00075	40	.059	ISLAND
13	55.40	10150	10.05									
				9600	10.35	850	47 500	5.20	.00052	71	.032	
14	54.94	9050	10.64									
						BELOW PARK ST BRIDGE						
16												
	GAGE 5.2	AVE AREA 16-17		1065	2.95	1000	2 500	2.36	.00064	54	.033	
	" 9.0	"	"	2958	5.97		12 400	4.20	.00065	67	.030	
	" 12.5	"	"	4755	8.90		25 450	5.36	.00067	70	.031	
	" 17.5	"	"	7505	13.10		47 500	6.33	.00069	67	.035	
17												
	" 5.2	AVE AREA 17-18		990	2.43	2300	2 500	2.52	.00064	64	.027	
	" 9.0	"	"	3380	6.17		12 400	3.67	.00065	58	.036	
	" 12.5	"	"	5920	7.12		25 450	4.31	.00067	67	.032	
	" 17.5	"	"	10 415	11.56		47 500	4.55	.00069	51	.048	
18												
	" 5.2	AVE AREA 18-19		1250	3.00	2600	2 500	2.00	.00064	46	.038	
	" 9.0	"	"	3130	6.47		12 400	3.96	.00065	61	.035	
	" 12.5	"	"	5480	7.00 (ABOUT)		25 450	4.65	.00067	68	.031	
	" 17.5	"	"	10 110	9.97		47 500	4.73	.00069	57	.040	
19												

*, C IN FORMULA, $V = C\sqrt{rs}$
†, n IN KUTTERS FORMULA.

C. B. STEWART, CONS. ENGR., MADISON, WIS.

sonable value, making the effective elevation of the pond for the flood of July 24th, 5:00 a. m. equal to 1,261.0 feet + 0.7 feet =

1,261.7 feet. At this time the tail water elevation was 1,260.5 feet. The results of the computations to determine the flow over the dam under these conditions is given in Table No. 3 and amounts to 26,545 second feet, practically agreeing with the assumed flood flow at this point of 27,400 second feet.

Break in Dam.—Two sizes of breaks have been considered, first the most probable one of about 600 square feet to the high water line (See Fig. 14), as shown from such evidence as could be gathered in the field, and second an extreme assumption of about 900 square feet to the high water line, as the break existed in October, 1913. The comparison of the effect of these two breaks will thus give information as to possible error in the assumption as to the size of the break.

TABLE NO 3
SHOWING
COMPUTATIONS OF FLOW OVER MERRILL BOOM COS DAM
FLOOD FLOW OF JULY 23-24, 1912
C. B STEWART, CONS ENGR, MADISON WIS

DESCRIPTION	WIDTH FT	REMARKS	ELEV. TAILWATER=1257.2, ABOUT 1 AM					ELEV TAILWATER=1260.5, ABOUT 5 AM			
			EFFECTIVE EL OF POND = OBS EL + 1.3 $\frac{V^2}{2g}$					= OBS. EL. OF POND + 0.7'			
			(1)	1259.9	1260.4	1261.0	1262.0	1261.7		1262.0	
			COEFF C	DISCH	DISCH	DISCH	DISCH	COEFF. C	DISCH	COEFF. C	DISCH
GATE 1	5.3'	WATER FLOW'G OVER TOP OF FISHWAY, EL TOP=1254.9	2.64	148	160	210	264	2.40	230	2.48	245
	6.3	" " " " " PIER " " =1259.1	2.64	12	25	43	82	2.64	70	2.64	81
" 2	12.0	" " " " " " " " =1259.1	2.64	24	48	82	155	2.64	138	2.64	155
	2.5	" " THRU PART OF GATE, EL SILL=1253.1	2.95	130	145	165	195	2.35	150	2.65	175
" 3	14.0	GATE OPEN; SUBMERGED OPENING 7'x14' " " =1253.2	2.95 (6)	710	800	900	1070	0.80	690	0.80	773
" 4	14.0	GATE CLOSED; EL TOP OF GATE =1257.0	3.33	228	294	374	522	2.00	286	2.20	345
" 5	14.0	GATE OPEN; SUBM OPENING 7'x14' EL SILL =1253.3	2.95	705	785	883	1060	0.80 (2)	690	0.80	773
" 6&7	29.0	SUPPORT BETW 6&7 WASHED OUT " " =1252.4	2.95	1750	1930	2155	2540	2.20	1800	2.60	2240
" 8	20.0	GATE OPEN, SUBM OPENING 7'x20' " " =1251.6	2.95	1410	1540	1700	1980	0.80	985	0.80	1100
" 9	10.0	GATE CLOSED " TOP =1255.6	3.33	296	350	418	540	1.85	280	1.93	312
" 10	14.0	GATE OUT EL. SILL =1251.6	2.95	990	1075	1190	1380	2.10	950	2.54	1190
" 11	14.0	" " " " =1251.6	2.95	990	1075	1190	1380	2.10	950	2.54	1190
" 12	14.0	" " " " =1251.6	2.95	990	1075	1190	1380	2.10	950	2.54	1190
" 13	14.0	GATE OPEN, SUBM. OPENING 7'x14' " =1251.6	2.95	990	1075	1190	1380	0.80	690	0.80	773
" 14	14.0	" " " " 7x14 " " =1251.6	2.95	990	1075	1190	1380	0.80	690	0.80	773
" 15	14.0	GATE CLOSED EL TOP =1258.8	3.33	415	490	582	755	1.85	393	1.93	437
" 16	14.0	GATE OUT, B'MSTICK FRONT GATE; SUBM OPEN'G 7'x14'	2.95	990	1075	1190	1380	0.80	690	0.80	773
" 17	14.0	" " " " " " " 7x14	2.95	990	1075	1190	1380	0.80	690	0.80	773
SPILLWAY	133.0	EL. CREST=1258.0	2.95	990	1400	1970	3030	2.80	2660	2.88	3050
GATE 18	8.0	LOGWAY GATE OUT EL SILL =1250.5	2.95	680	735	800	920	2.35	705	2.50	780
SPILLWAY	123.5	EL. CREST =1257.9	2.85	988	1370	1920	2920	2.80	2540	2.85	2920
"	148.5	" " =1258.5	2.85	720	1100	1890	2750	2.90	2460	2.85	2750
SP'Y WITHOUT BR'K.	105.0	" " =1258.9	2.85	300	540	900	1645	2.95 (3)	1450	2.85	1640
WITH BR'K 600 SQ FT	105.0	BREAK ALONE TO HIGH WATER MARK	2.64	(3494)	(3800)			2.64 ξ	(4590)	2.64 ξ	(5700)
" " 900 " "	105.0	" " " " " "	2.64	(7080)	(7702)			2.64 ξ	(6112)	2.64 ξ	(7584)
SPILLWAY	35.0	EL: CREST=1259.0	2.64	83	170	260	480	2.64	407	2.64	480
DIKE	75.0		2.64	435	650	930	1460	2.64	1290		1460
DIKE	120.0				95	190	700	2.64	540		700
DIKE	15.0						27	2.64	16		27
TOTALS				16951 (5)	20152	24509	32755		23405		27090
TOTALS WITH 600 SQ. FT. BREAK SUBSTITUTED				20145	25412			(4)	26545		31180
" " 900 " " " "				23731	27514				28067		33054

NOTES (1) COEFF C FOR USE IN FORMULA, $Q = CLH^{3/2}$
(2) " C " " " " " , Q = CA√2gh
(3) COEFF FOR FLAT CREST DAM = 2.64; ξ = EFFECT OF SUBMERGENCE, BREAK DIVIDED INTO WIDTHS OF ABOUT 10' AND DISCHARGE THRU SEPARATE PARTS ADDED
(4) = APPROX. FLOOD FLOW JULY 24, 5 AM AFTER BREAK OF 600 SQ. FT.
(5) = " " " JULY 24, 1 AM BEFORE BREAK OCCURRED.
(6) = GATE OPEN 7, EL BOTTOM OF GATE = 1260.2, WATER DRAW DOWN UNDER BOTTOM OF GATE.

Coefficients for Computing Flow Over Submerged Dams.—Our experimental knowledge concerning the flow over submerged dams is very meager. Practically the only reliable experiments in this country have been on sharp crest dams or weirs by Francis and Fteley and Stearns and on a single round crest dam by the U. S. Board of Engineers on Deep Waterways. Fortunately, Mr. M. H. Bazin, of France, in his extended experiments on weirs, also made a quite complete set of experiments on submerged weirs. The writer has made a careful investigation of Mr. Bazin's experiments on weirs, both with free fall and submerged, and from these experiments on certain forms or cross sections of dams has deduced re-

sults for the particular form of the Merrill Boom Company's dam. The form of the cross section of the spillway of the Merrill Boom Company's dam is shown on Fig. 9. It will be seen that the dam has a flat crest 2 feet wide, the up-stream apron having a batter of 2:1, while the down-stream apron has a batter of 12 to 1. The figure shows that the coefficient C of the formula $Q = ClH^{3/2}$ for weirs, of the form of the Merrill Boom Company's dam without submergence of the crest would be about 2.95 for heads from 4 feet to 8 feet and about 2.85 for heads from 2 feet to 4 feet.

The effect on the coefficient C, of submerging the crest of the dam is shown on Figs. 10 and 11, for each of the forms of cross section experimented on by Mr. Bazin. Figure 12 shows, in graphical form, the effect of submergence on the coefficient C for various

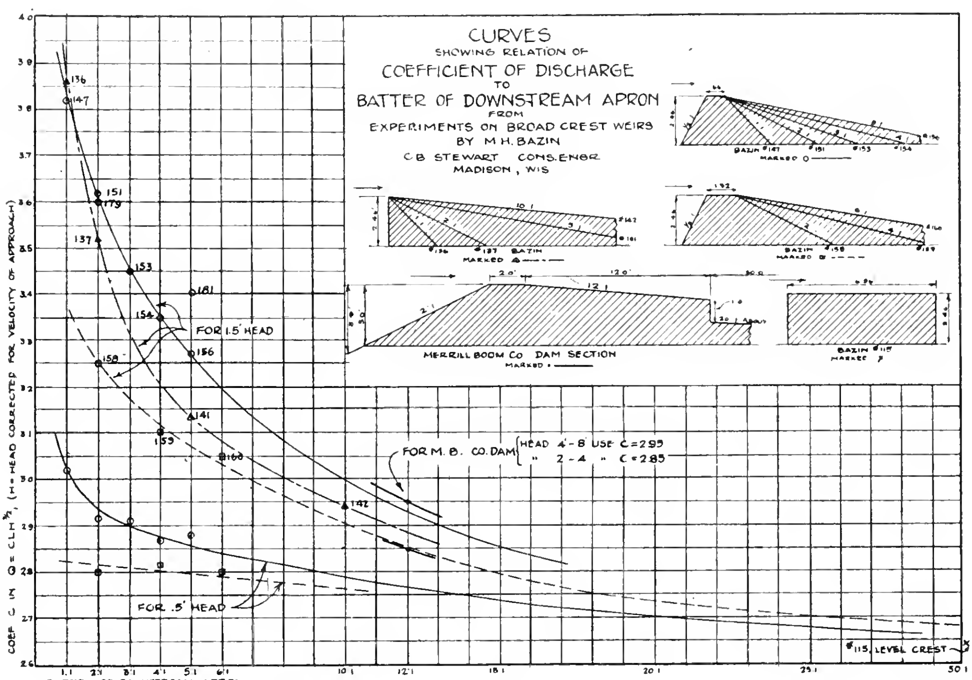


Fig. 9.

forms of weirs and dams. It will be noted that the effect of submergence is much greater for sharp crest weirs than for wide crest weirs. That for 90% submergence the coefficient of discharge will be about 90% of the coefficient of discharge without submergence for all dams where the slope of the down-stream apron is less than 5 to 1. Figure 13 shows that for the Merrill Boom Company's dam, with a slope of the down-stream apron of 12 to 1, that a submergence of 80% will only reduce the coefficient of discharge by about 2%.

Discharge Curve of the Merrill Boom Company's Dam.—Figure 14 shows the approximate discharge curve of the Merrill Boom Company's dam for the various assumed conditions for which the discharge has been computed and given in Table No. 3. At 1:00

a. m. the tail water elevation was about 1,257.2 feet, this elevation giving the same proportional rise for the water at the Merrill Boom Company's dam as occurred at the Merrill Railway & Lighting Com-

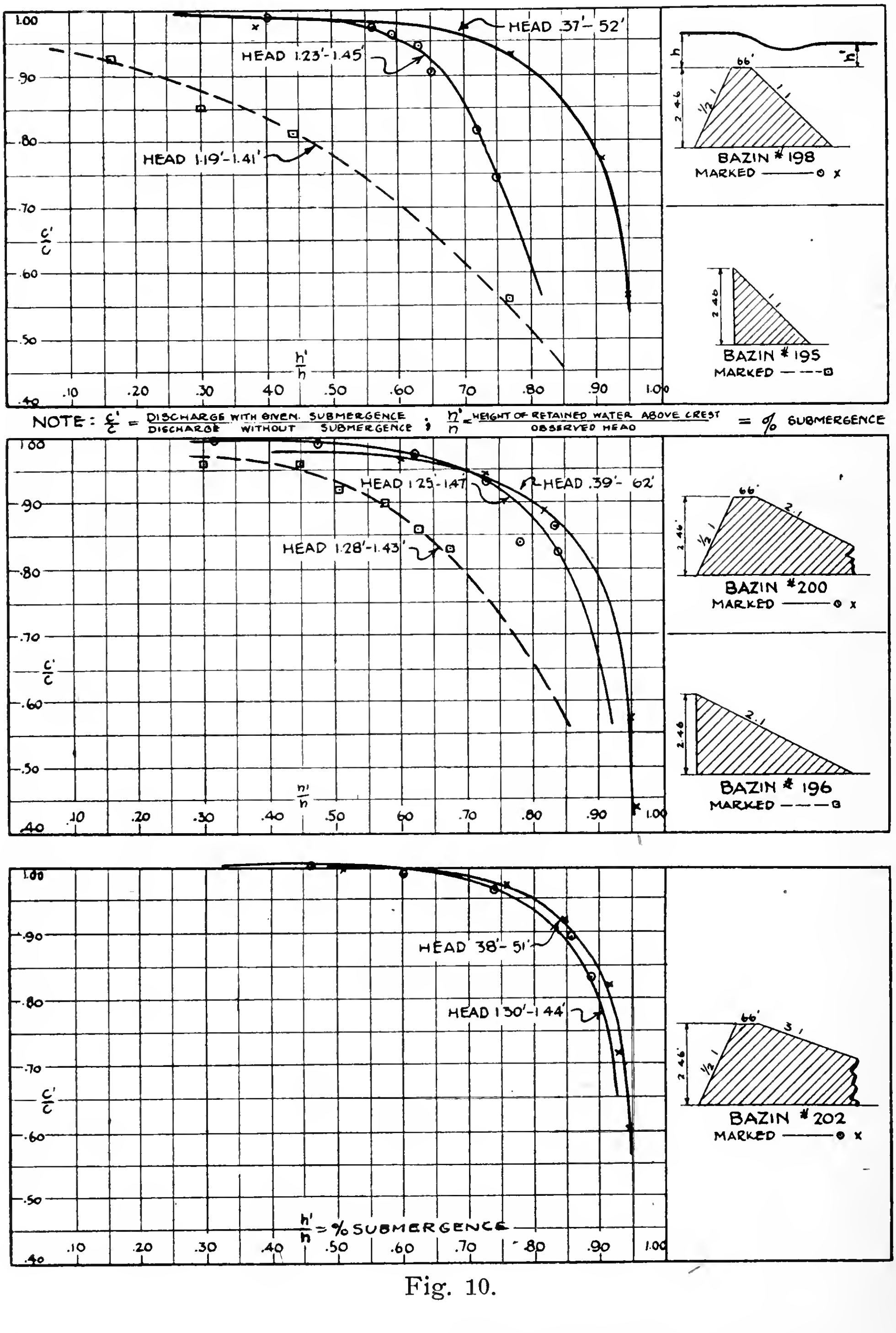


Fig. 10.

pany's dam. The tailwater at the Merrill Boom Company's dam gradually raised from this elevation to 1,260.5 feet, thus causing a

gradually increasing percentage of submergence in the sluice gates of the dam.

Curves A, B and C represent the discharge curves with the

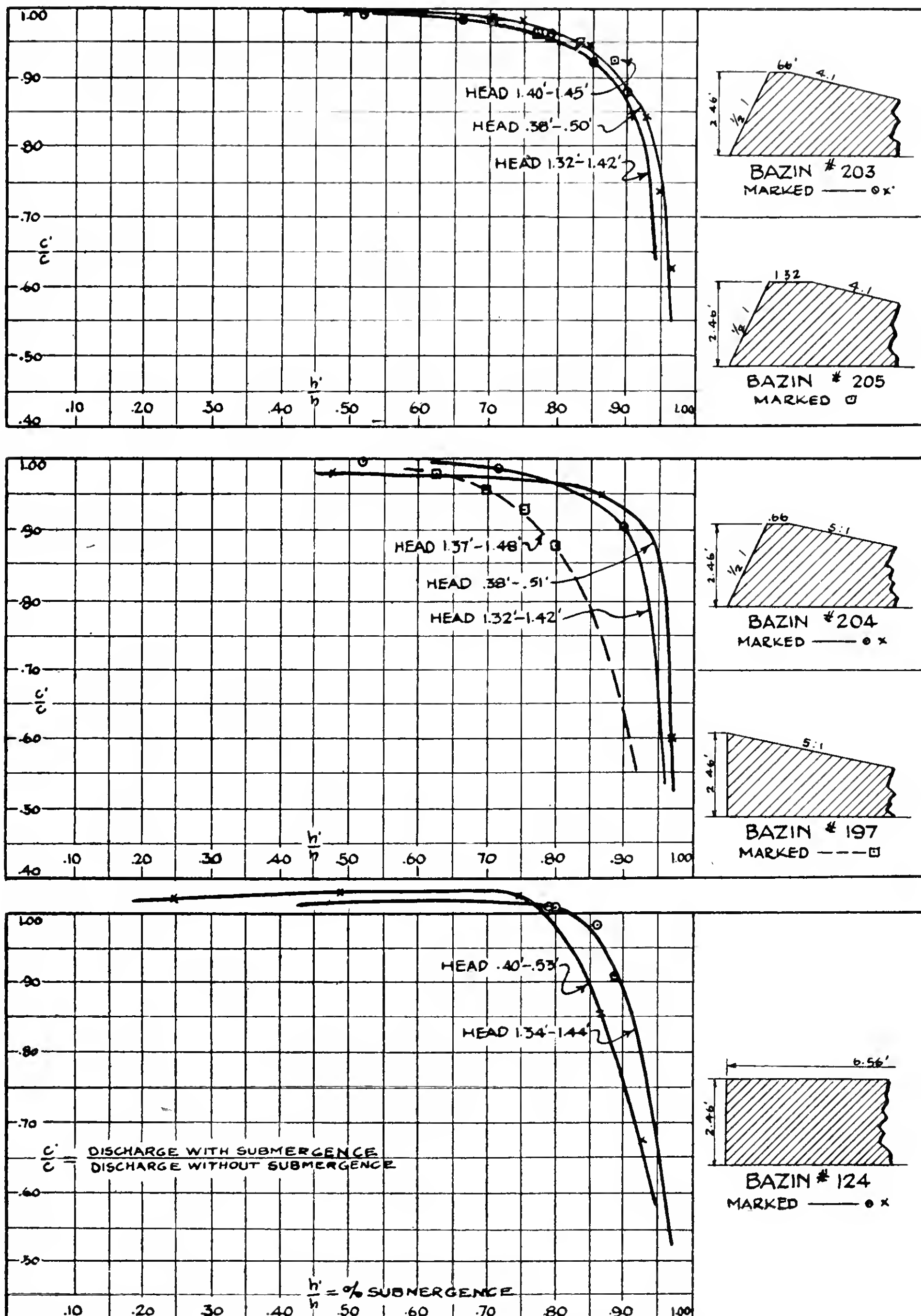


Fig. 11.

tailwater remaining at elevation 1,257.2, A without break, B with break of 600 square feet, and C with break of 900 square feet. In

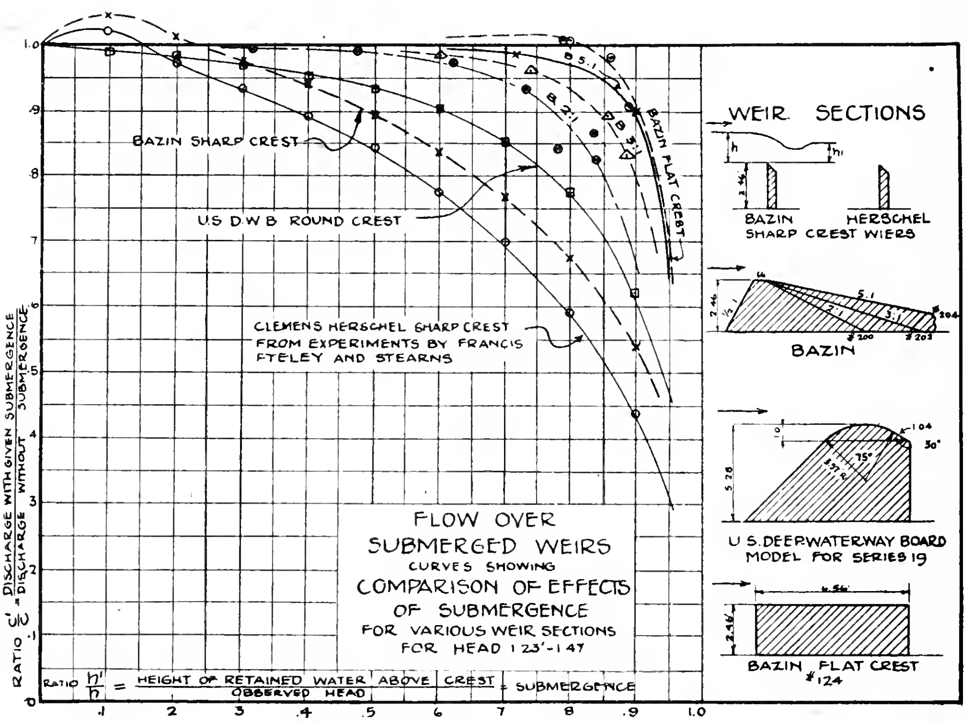

WEIR SECTIONS
BAZIN HERSCHEL
SHARP CREST WIERS
BAZIN
U.S. DEEPWATERWAY BOARD
MODEL FOR SERIES 19
BAZIN FLAT CREST
#124
BAZIN SHARP CREST
U.S D.W.B ROUND CREST
BAZIN FLAT CREST
CLEMENS HERSCHEL SHARP CREST
FROM EXPERIMENTS BY FRANCIS
FTELEY AND STEARNS
FLOW OVER
SUBMERGED WEIRS
CURVES SHOWING
COMPARISON OF EFFECTS
OF SUBMERGENCE
FOR VARIOUS WEIR SECTIONS
FOR HEAD 1.23'-1.47
RATIO $\frac{c'}{c}$ = $\frac{\text{DISCHARGE WITH GIVEN SUBMERGENCE}}{\text{DISCHARGE WITHOUT SUBMERGENCE}}$
RATIO $\frac{h'}{h}$ = $\frac{\text{HEIGHT OF RETAINED WATER ABOVE CREST}}{\text{OBSERVED HEAD}}$ = SUBMERGENCE

Fig. 12.

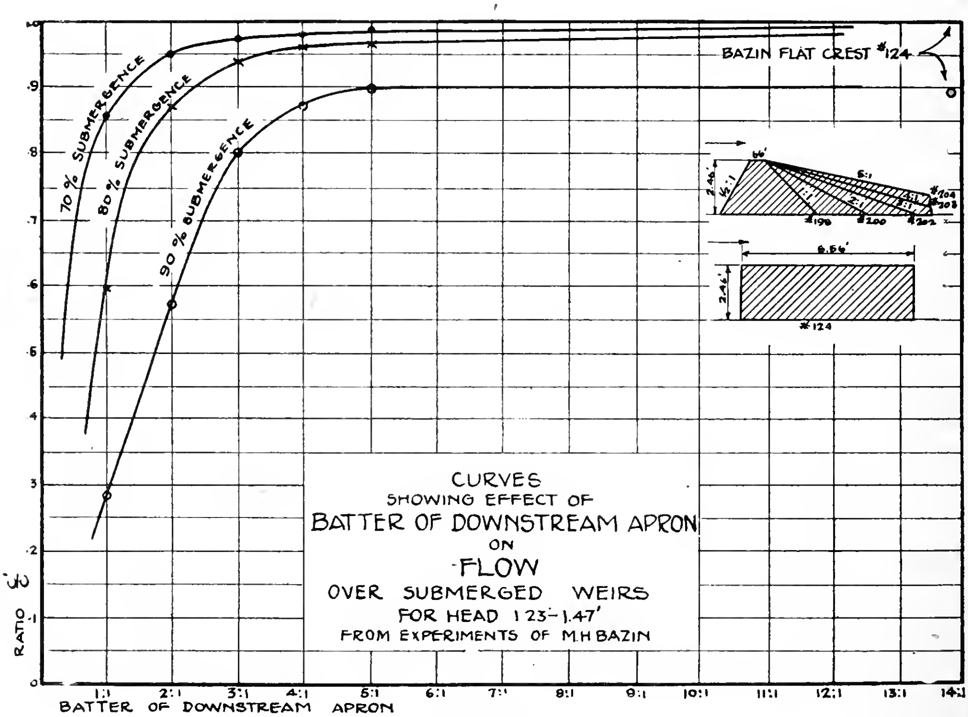

70% SUBMERGENCE
80% SUBMERGENCE
90% SUBMERGENCE
BAZIN FLAT CREST #124
#124
CURVES
SHOWING EFFECT OF
BATTER OF DOWNSTREAM APRON
ON
FLOW
OVER SUBMERGED WEIRS
FOR HEAD 1.23'-1.47'
FROM EXPERIMENTS OF M.H BAZIN
RATIO $\frac{c'}{c}$
BATTER OF DOWNSTREAM APRON

Fig. 13.

computing the flow through the break in the dam, the width of the break, 105 feet, was divided into widths of about 10 feet, and the discharge through the separate parts computed as though they were flat crest dams. This method would give a discharge somewhat in excess of what actually occurred and so could not be objected to.

Curves A′, B′ and C′ represent in the same way the discharge curves with the tailwater remaining at elevation 1,260.5.

It is impossible to determine at what time the break in the dam occurred. We will assume the extreme condition that the break occurred at 1:00 a. m. with a normal flow of 20,000 second feet, when the water was just at the point of overflowing the dyke of the Merrill Railway Lighting Company's dam. The curves show that for a break of 600 square feet the discharge would be increased by 3,400 second feet, and that the water in the pond of the Merrill Boom

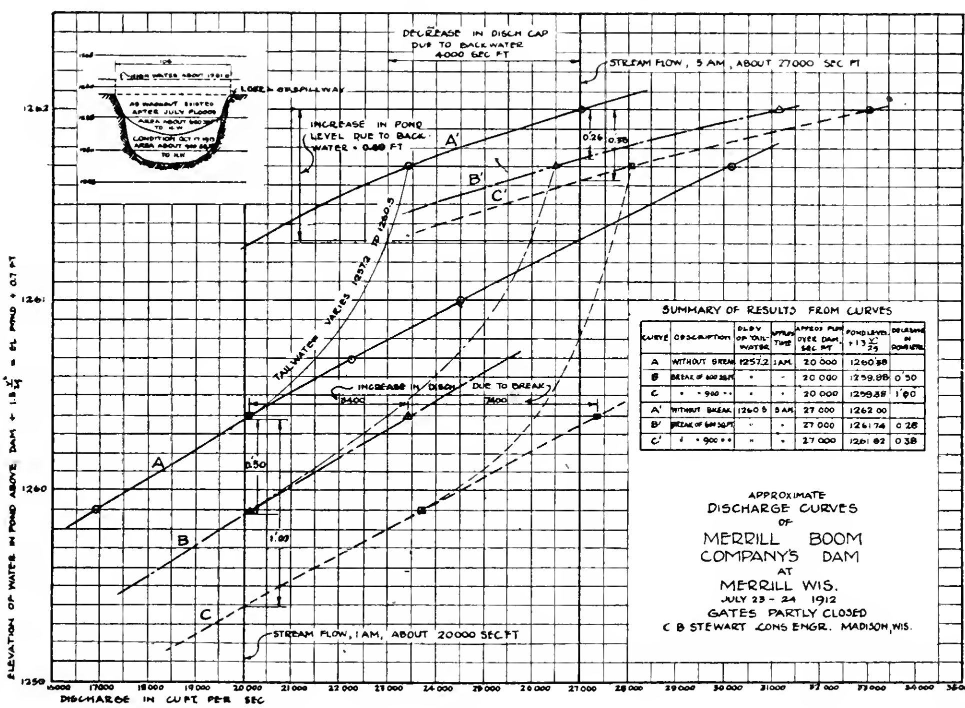


Fig. 14.

Company would be gradually lowered by the amount of 0.5 feet, at which elevation the flow would again be the normal amount of 20,000 second feet. In the same way for a break of 900 square feet, the discharge would be increased by 7,400 second feet, and the pond gradually lowered by the amount of 1.0 feet.

Effect of the Break in the Merrill Boom Company's Dam on the Discharge at the Merrill Railway & Lighting Company's Dam.—Figure 15 shows the relation of time to elevation of the ponds of the Merrill Boom Company and Merrill Railway & Lighting Company, and also the relation of the time to the change of inflow and of outflow resulting from the changes in elevation of the ponds. The

inflow through the break in the dam of the Merrill Boom Company gradually decreases, and at the same time the outflow from the pond of the Merrill Railway & Lighting Company gradually increases in proportion to the rise of water level, as shown by the discharge

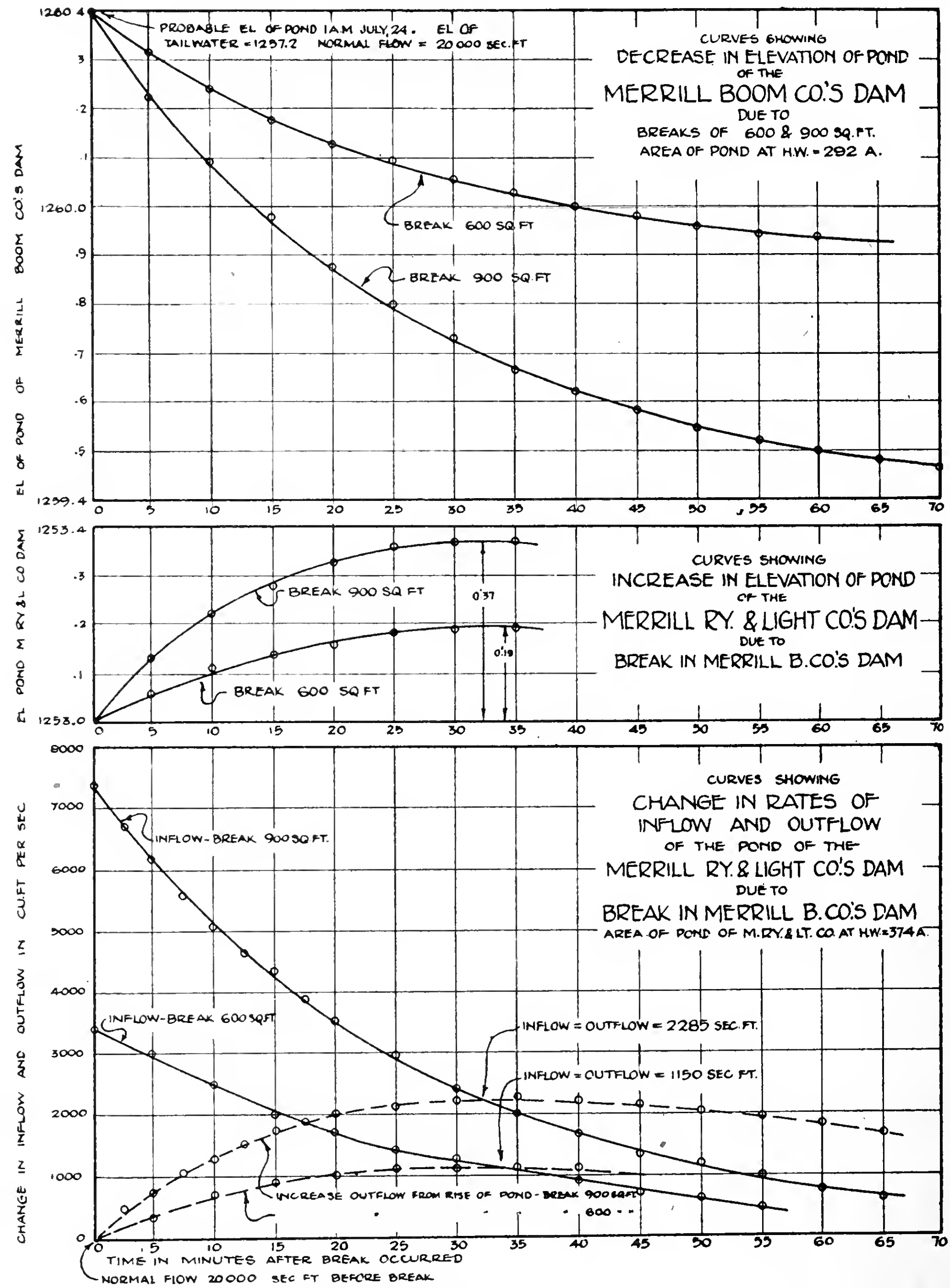


Fig. 15.

curve, Fig. 7. After some period of time, found to be about one-half hour, the inflow due to the break will be just equal to the increase of outflow resulting from the rise in the pond, and this will be the

maximum increase in discharge due to the break. For the break of 600 square feet the resulting rise in the pond of the Merrill Railway & Lighting Company reached a maximum of 0.19 feet, and caused an increase in discharge of 1,150 second feet. For the break of 900 square feet the resulting rise would be a maximum of 0.37 feet and cause an increase in discharge of 2,280 second feet.

The curves and results are based on an area of pond of the Merrill Railway & Lighting Company at high water, of 374 acres, and of the Merrill Boom Company at high water of 292 acres. The assumption is made that the pond of the Merrill Boom Company extends to old dam No. 2, and that the decrease of pond level of 0.5 feet and 1.0 feet would extend over the whole pond to old dam No. 2. It can be shown that for the decrease of pond level of 0.5 feet at the Merrill Boom Company's dam that the two backwater curves, when discharging 20,000 second feet, would practically coincide at old dam No. 2, so that the average depth which the pond would be lowered would be about 0.25 foot.

The results from the curves showing that an increase of discharge of 1,150 second feet would occur at the Merrill Railway & Lighting Company's dam, as a result of the break of 600 square feet is, therefore, somewhat too large. It is probable that, allowing for the backwater as stated, and considering that the break of 600 square feet could not occur suddenly, that the increase in discharge did not exceed 50% of the value, 1,150 second feet, as stated. This would make the increase in discharge about 575 second feet, and the rise in the pond a maximum of about 0.10 foot.

The curves, Fig. 15, show that after the maximum rise in the pond has occurred, the inflow becomes less than the outflow, so the pond level gradually decreases. With the break occurring at 1:00 a. m., it can be shown that by about 2:30 a. m. the effect of the break will practically have passed. Should the break have occurred at a later time, about 5:00 a. m., Fig. 14 shows that for a break of 600 square feet the pond of the Merrill Boom Company would have been lowered 0.26 foot, or about one-half the amount at 1:00 a. m. The effect on the pond of the Merrill Railway & Lighting Company would also have been about one-half the values for 1:00 a. m., giving an increase of discharge of 288 second feet, and an increase of pond level of 0.05 foot.

It has been shown that the flood flow at 5:00 a. m. at the Merrill Railway & Lighting Company's dam was 47,500 second feet, and that the flood capacity of the Merrill Railway & Lighting Company's dam, when the water overflowed the dyke, was 33,300 second feet. There was, therefore, 14,200 second feet of discharge required to be taken care of over and above the flood capacity of the dam. The maximum effect of the break, about 576 second feet at 1:00 a. m., could not, therefore, have exceeded about 4% of the total excess to be taken care of to prevent the failure of the dam, while at 5:00 a. m. the effect would have been about 288 second feet, or about 2% of the excess to prevent failure of the dam.

November, 1916

The writer desires, in closing, to thank the officers for the Chicago, Milwaukee & St. Paul Railway Company for the means of carrying out this investigation, and to acknowledge the valuable assistance of Mr. F. D. Yeaton and Mr. W. B. Swartwout, formerly assistant engineers of the C., M. & St. P. Ry., in carrying out the field work in connection therewith.

DISCUSSION.

Chairman DeBerard: What length of time was allowed between the upper and the lower dams in your curves. Of course, you could not get an instantaneous result, but about what would be the period from the break of the upper dam until the effect was felt below?

Mr. Stewart: The break in the upper dam was considered as causing a gradual rise in the entire pond below the break. The pond was one body of water 2.3 miles long and about 1,000 feet wide, and although some short time period would be required for the effect of the break to be felt at the lower dam, the assumption was such as to show greater effect at the lower dam than actually occurred.

E. N. Layfield, M. W. S. E.: I understand that this investigation was made as a result of a law suit. And as I have had the pleasure of being on the witness stand a number of times I am curious to know just how the court and jury viewed these assumptions which are convincing enough to an engineer, but give an opportunity to a lawyer to ask you why you assume that it might have happened at one o'clock, or it might have happened at five o'clock, and so forth. I am curious to know just how this kind of testimony impressed the lawyers and the jury and the court.

Mr. Stewart: I would say that we were fortunate in having a very good judge in the case, who was inclined to treat me as an expert and not be technical. I went over a portion of the testimony in outline, but was not required to go into detail.

Mr. Layfield: Of course, I understand that when a witness is admitted as an expert on certain subjects he is not subjected to quite the same kind of cross examination that a man is who is called as an eye witness to something that may or may not have happened. So, of course, if the judge was friendly and admitted the evidence, it made it so very much easier.

Chairman DeBerard: You did not tell us what the result of the law suit was.

Mr. Stewart: It was won by the defendant. I showed quite conclusively that no matter when the accident occurred, either at 1 a. m. or at 5 a. m., that there was a flow of about 14,200 cubic feet per second over and above the flood capacity of the dam, and that of this amount only from 2 to 4 per cent could have been caused by the break, so the dam would have failed any way.

Chairman DeBerard: Was that proposition self-evident before you started in on it?

Mr. Stewart: No, I did not know the result before I started the investigation.

Chairman DeBerard: No layman, court, or even an engineer could predict the result?

Mr. Stewart: I do not believe so, without investigation.

George E. Ackerman, M. W. S. E.: Mr. Stewart's conclusion was that the maximum flood flow was something over 90 cubic feet per second per square mile. Are we to draw the conclusion that all future dams in that region should be designed for that maximum flood flow?

Mr. Stewart: The flow of 96 cubic feet per second per square mile was from 450 square miles of drainage area. The entire drainage area above Merrill is about 2,600 square miles, so that the flood flow of 47,500 cubic feet per second gave a run-off of 18.3 cubic feet per second per square mile. The topographic conditions at Merrill are such as would produce a large flood flow when heavy rains occur. At other points in the vicinity the conditions are not similar to those at Merrill and it would not follow that the same flood flow capacity would be required at all points.

Mr. Ackerman: Isn't it true that very few dams are designed for that flood flow per square mile?

Mr. Stewart: The largest flood flow that has occurred at Merrill previous to this was apparently about 25,000 cubic feet per second, and this was considered a very large flood flow.

Experience is showing that the amount of flood flow which may occur on any given river, is usually very much more than the ordinary layman, and possibly some engineers, would consider possible. With information available as to the amount of flood flow on various rivers resulting from heavy rainfalls, as at Merrill, Black River Falls, in the Miami Valley and other places, it has become possible to predict what may result at other places under similar rainfall conditions. These heavy flood flows may occur only once in a hundred years, but if life is endangered provision must be made for them. If property only is endangered, it may be advisable to cut down the required flood capacity of the dam or stream in accordance with our judgment. As the country becomes more thickly settled, the question of provision for flood flow in our streams becomes more and more important.

Mr. Ackerman: There is probably no other class of engineering structure put up in the West that has been built with less regard to fundamental principles of engineering than the dams in the streams of the Northwest. In fact, I believe the great majority of the dams all through the Northwest have been built, not by engineers, but by old millwrights who paid not the slightest regard to the fundamental hydraulic principles, and that is one reason, I think, why so many of the northwestern dams failed during the last few years. I sincerely hope that that time is passing, and that future dams will be designed, rather than just built.

Ernest McCullough, M. W. S. E.: The question of what a dam should be expected to withstand is important. The amount of flood flow to provide for is important. The Miami Conservancy Commis-

sion decided that the new works designed to protect Dayton against another flood should carry 40% more water than the largest recorded flood, which was in 1913. In a discussion before the American Society of Civil Engineers in 1912, Mr. Fuller stated that once in a hundred years a flood 2.8 times in excess of the average flood flow might be expected. Ordinarily it is expected that about once in thirty-five years a flood of considerable magnitude in excess of other floods may be looked for. Otherwise the high and low water periods are apparently lawless. Professor Moore, in his Study of Economic Cycles, a few years ago applied Fourier's Theorem, which is usually applied only to harmonic analysis, to his study of rainfall in the Ohio Valley and the State of Illinois. The harmonic curve fitted the graph of rainfall records remarkably. While the maximum and minimum points were not reached in magnitude they were indicated in position—a very interesting similarity.

In the northwest, that is in the Missouri-Mississippi basin, the rainfall is not so great as it is in the Ohio Valley. The flood records are meager, but apparently the flood curve is approaching the early months of the year. The big floods formerly came in June, but now they come in March, April or May. This may be due to the fact that more ground is cleared and more streets paved and less water is absorbed by the ground as the forests disappear. When early rains used to melt the snow, and the grass and leaf covered soil absorbed the water, it was stored. Now they come on frozen ground and the water goes more quickly to the main water courses.

In Minnesota and Wisconsin, in all the mid-western states in fact, the old dams were built by millwrights and the power demands were small. There were no rainfall records to guide them and the villages were so small that no one worried about the effect of a dam breaking. The rule of thumb methods of the old generation of dam builders have been slavishly followed on larger dams, and it is surprising that we do not have more failures. The trouble has been the lack of rainfall data and it is time all plans for dams were approved by competent authority.

Chairman DeBerard: Of course you all know that we cannot design to take care of every contingency, which it is possible may come once in a hundred years. The O. K. Creek sewer in Kansas City will overflow some time, but the Kansas City Railway Terminal Commission figured out that the damages would be less than to allow for that flood which must come in fifty or a hundred years. And that is where the judgment, perhaps of this generation, may seem foolish in a good many instances half a century hence, when that big flood comes. I have heard Mr. L. E. Cooley talk about the flood that is coming in the Illinois River. He said that the flood in the Miami Valley would then look small, and I have no doubt that the flood which he has predicted will come to pass in the lifetime of some of us. I also do not question the data that he has gathered, and that means that we can continue to look for disasters of this kind, although we haven't the money or the authority to prevent it.

In the case of the Miami flood it was very easy to hear at the time the story of the old Indian legend about building your house up on the high land. The Indians would not build down in the flat country in the vicinity of Dayton for they had seen floods covering the whole of the site where Dayton is located. Dayton is practically a spillway with flat country back of it.

President Grant: This seems to me like an exceedingly able analysis of a highly interesting problem, and I hope that the engineer who made it receives as much compensation as the lawyer who participated in the suit, though I have my doubts on that subject. I would like to ask Mr. Stewart one or two questions. He spoke of some investigation as to the cross section of the river at various points. I am wondering what actual work he did in the field, and how long a time it covered, and the approximate cost of it. Also what has been done with the dams there since that flood. Were they restored?

Mr. Stewart: The length of time of the investigation I should judge must have been about two months. The work was started under the direction of the engineers of the Chicago, Milwaukee & St. Paul Railway. I was not called in until about the last three or four weeks of the investigation.

They must have had about five or six men at work at least two months. They made a complete topographical survey of the river for a length of about four miles, traced out the flood plane and took numerous cross-sections of the river up to the flood plane.

I do not know the expense, but you can estimate it from the number of men and the length of time, and arrive at the approximate cost.

The old timber crib dam has been replaced by a concrete dam.

Murray Blanchard, M. W. S. E.: The point has been brought out in regard to the discharge curve being affected by the construction of bridges and other works along the streams. I had occasion recently to investigate a discharge curve which had been previously well determined. A concrete arch bridge had been built several hundred feet below where the rating curve was taken, and the effect was to alter the discharge curve for flood flows 25 per cent at the highest stage observed, a very considerable change.

The Geological Survey furnishes extensive data carefully worked out for streams all over the country. Many engineers are apt to take this without question as reliable, but when one realizes that construction work in reaches under consideration may effect the discharge curve so much, the importance of further investigation is seen. Then there are other uncertainties that we have to deal with, as the author has pointed out such as the lack of data in regard to the flow over dams. Any one with the author's experience would, no doubt, investigate these points, but engineers have to scrutinize carefully even data published by standard authorities to avoid mistakes.

The increase in the use of current meters has shown up defects

in meters generally considered as accurate. The Geological Survey has recently discontinued the use of the large price current meter of the cup wheel type, which cannot be depended upon for constancy of rate.

Experiments made in connection with meter ratings in the naval tank at the University of Michigan, show how the rates are changed by varying the condition of the meter, as by wear or careless handling in current measurements:

(a) Blunting the point of a large Price meter caused a change in the rate of 8%.

(b) A difference of 7% occurred between the rate of a Haskell meter run with no oil on the bearings and with a large excess of oil on them.

(c) Varying the stiffness of the contact spring of a Haskell meter changed its rate.

(d) A large Price meter was rated and a good curve obtained before noon, the meter was left suspended in the water an hour or more at noon and then rerated. The second curve was as good as the first but differed from it by 10%.

The matter of the different types of meters was discussed in the transactions of the American Society of Civil Engineers, in an article by Mr. B. F. Groat, Vol. LXXVI (1913,) pages 819-870. He found a Haskell meter to be in error 1% when a Price meter was in error 6%.

Discharge curves for flood flows obtained without the accurate knowledge of the rate of the meters used might be in error and greatly effect such investigations as the author has described tonight.

Mr. McCullough: Some time ago, I think it was about the time that the Black River Falls dam failed, there was some agitation for Government regulation of the construction of dams. Has there been any legislation in that matter since then, either by state or federal government?

Mr. Stewart: In the state of Wisconsin we have the State Railroad Commission who have to approve the plans of all dams, before they can be constructed.

Mr. McCullough: Have similar laws been passed in other states?

Mr. Stewart: I believe several states have somewhat similar laws.

In Wisconsin the water power laws also attempt to regulate obstructions in streams, and a test case has recently been made at Janesville, Wisconsin. In the early fifties the State Legislature granted the right to a man to erect a butcher shop on a bridge pier in the middle of the stream. The laws of rivers in Wisconsin are such that the riparian owns the bed of the stream to the middle subject to the right of navigation. After this man had erected and maintained his butcher shop, the riparians adjoining him on each side also occupied the river, putting their buildings on piles. As a result there were buildings on one side of the bridge extending across

the river. The water power law is such as I recall it, that when complaint is made the Railroad Commission must make an investigation and report their findings to the governor of the state. If they find an obstruction exists, the Attorney General must commence suit against the riparian to remove the obstruction. This case was tried about a month ago, and a number of expert hydraulic engieeers testified as to the flood menace and danger to life and property. I believe it is the intention to carry the case to the Supreme Court as quite similar conditions of obstruction exist at a number of points in the state.

Mr. Ackerman: I think the Wisconsin law is to be especially commended, inasmuch as the Railroad Commission have complete supervision over all dams and all changes in dams. That is, the owner of a dam can make no change whatever in the dam without submitting drawings showing the proposed changes to the railroad commission and having the commission's approval of such changes. Likewise, no new dam can be constructed in the state without the design being passed upon by the Railroad Commission. I believe when we have that law in every state it will be a very desirable condition to have.

In Illinois, the Rivers and Lakes Commission have about the same authority over dams, as I understand it.

G. W. Stickney: In connection with that matter, I would like to state on behalf of the Rivers and Lakes Commission, of which I am at present one of the engineers, that the commission in this state has *complete* jurisdiction over all the navigable waters of the state, and it also has the jurisdiction over *all* waters as regards pollution and encroachments, and the placing of dams or obstructions of any sort. No dam can be placed in any of the waters of the state of Illinois at the present time without the consent of the Rivers and Lakes Commission, and then, of course, under stipulations as to the height and length of the crest and so forth. We do not pretend to pass so much on the safety and stability of the dam as the question of rights of riparian owners and the possibility of flooding the lands adjacent. And in that connection there have been a number of cases which have been taken up in recent times. I have in mind one case in particular where a change was made in the power house at a certain dam a number of years ago, and the debris from the old building was so disposed that it obstructed a portion of the crest of the dam. The Rivers and Lakes Commission issued orders for that obstruction to be removed and the original condition restored. This is merely an illustration of cases which are coming up continually.

Chairman DeBerard: Have any of those cases been carried through the Supreme Court by the Rivers and Lakes Commission?

Mr. Stickney: The question of the authority of the Rivers and Lakes Commission has been established in these matters. Of course, when it comes to the removal of obstructions, or encroachments

which are of long standing, there is often a question of policy, perhaps, as well as the question of the rights of owners. For instance, where a manufacturing institution or plant has built out into what is really a portion of the flood area of the stream, and been there for a good many years, and perhaps has dumped cinders or other material in such a manner as to further decrease its capacity for carrying water during the flood season, it is very often a question as to just what is the best method of overcoming the difficulty, and in a good many cases the municipalities themselves are the worst offenders in this regard. So that sometimes it may be better policy to provide an auxiliary waterway, if possible, rather than to try to remove all of the obstructions which have been placed by the hand of man. The question of stream encroachment has become a serious one and this commission is doing everything in its power to provide and maintain better conditions for flood flow.

Chairman De Berard: Does your jurisdiction extend over navigable streams only?

Mr. Stickney: No. In cases of encroachment it covers all streams, as I understand it, and also in the matter of pollution.

Whenever complaint is entered regarding the pollution of a stream, the case is investigated by the commission. And if necessary, a hearing is held and witnesses are called before the commission to determine whether the case is such as to warrant an order to the guilty ones to cease polluting the stream.

The same thing applies to encroachments. We are making surveys of the streams in the state as fast as we can to determine as nearly as possible what encroachments exist, and taking especial pains to prevent additional encroachments at the present time.

Of course, the exact line of the bank of a stream or lake, which really determines whether a structure or anything that is placed there is an encroachment, is an indefinite thing and hard to determine in many cases. The courts have ruled that the original meander lines do not necessarily determine the question.

Mr. Ackerman: It is very admirable to have such laws relating to rivers. I am wondering two things: First, if in these states that have commissions that put their approval on the construction of dams, if they shift the responsibility for the design and size and so on from the shoulders of the owner on to themselves, and, if so, if they have the facilities for really making a thorough investigation of the proposition in each case.

Now, I notice there has been quite a lot of money spent on the Merrill dam after it went down. And I am wondering if the state had ever spent that much money on the dam before it went down to find out if it really was stable under all conditions. And I should think that if there should be laws requiring that the state would approve the construction of dams that they would largely be responsible for those dams after they were built. Possibly some one can tell us about that.

W. G. Hoyt (By letter): Mr. Blanchard brought out several

points which may well be given more emphasis. Care should be exercised in using the published or unpublished records of flow to determine whether the maximum referred to is the maximum mean daily flow, or whether it is the flow corresponding to the maximum crest. On large rivers the difference is small, while on smaller rivers it may be considerable. Records of maximum stages should be investigated to determine if the control section for the point of observation was unobstructed at the time the record was made. On many streams in the northwest and elsewhere, abnormally high stages have been recorded with only correspondingly medium flows, due to the presence of ice and log jams or other obstructions.

Relative to care needed in using estimates made by determining flood flows over dams and other structures, the writer's attention was recently called to an estimate of flow made over a dam. From the published study it is not possible to determine whether account was taken of the flow through certain locks which were in the dam and which would discharge at the height under consideration some 20,000 or 30,000 second-feet. The accuracy of the figures given is therefore somewhat in doubt.

As to the use and errors in current meters: The Water Resources Branch of the U. S. Geological Survey discontinued the use of the large Price current meter some five or ten years ago, and has since that time used the small Price meter in ordinary river work. There are several types of meters on the market which have been devised to meet certain conditions, and which may not be adapted to other conditions. Differences in the position of the weight or other means of supporting the meter, blunting of the points, increasing pressure of contact springs, etc., will naturally change the rating of any meter, and care should therefore be taken to always use the meter as nearly as possible in the same condition as it was rated. To correct the impression that might be gained from reading Mr. Blanchard's discussion, that the Price meter may be 6% in error, and the Haskell meter 1% in error, the writer would like to bring out that the tests conducted by Mr. Groat were made where the physical conditions were unfit for current meter work, and entirely dissimilar from the conditions met with in ordinary river work. Moveover, evidence is not available to show that the true flow was found, so that it is impossible to determine the accuracy of the two meters from the tests which Mr. Groat has made.

In measuring floods with any type of current meter, care should be taken to see that sufficient weights are employed, or stay wires used, so that the meter will not swing out of the vertical. If there is an undue amount of pulsation and angularity of current at the time of measurement, there is a tendency for the Price meter to over-register, while the Haskell meter would probably under-register. In ordinary river work, any type of meter should give similar results if the ratings are carefully made and the meter used in its rated condition, it being understood, of course, that the meter in the first place is adapted to the work under consideration.

November, 1916

THE ENGINEER AND PUBLIC SERVICE.

Presented October 2, 1916.

Clarence T. Johnston.*

A democracy will ultimately fail unless the people thereof realize, within a reasonably early date in its history, that qualifications for public office must have first consideration. Until the business of the country is analyzed and trained men placed in charge of the various branches thereof, these places will be occupied by incompetent office-seekers. We know the type. The man who is trained to talk has an advantage over his less fortunate competitor which first brings him notoriety and then political support. He is promoted from one position to another as his political machine, oiled and manned at public expense, carries him on to a personal and selfish victory, regardless of his real usefulness to the people who unthinkingly support him. The noisy demagogue among the legal fraternity has a great advantage over his able, studious and strictly honest brethren. Under present conditions, therefore, political favors are inclined to go to the man who can imitate a statesman in appearance and in noise produced, regardless of his other qualifications for public service.

We are inclined to criticise some foreign governments because of manifest favoritism to certain classes. We very properly condemn any country which recognizes inherited rights to govern. Superficial acquaintance with some governments, which we ridicule because of the glaring defects they inherit, may lead us to draw conclusions of a general character which may not be supported when we obtain a more intimate acquaintance with the country. We may or may not approve of the methods of the German Junker. On the other hand, we must praise the engineering schools of Germany. We must praise the German government for the standing it gives engineers, and we must applaud the splendid work performed by these engineers for the people as individuals and for the state. We may feel that the government of England is defective in many respects. Living in a country which has regarded public service as an opportunity for private gain, we would be quick to condemn the inherited power and authority as represented in the British House of Lords, although we might soon be obliged to admit that even this antiquated system does afford men an opportunity to prepare for the responsibility that is to come to them.

Let us turn to the English colonies. We find in each a department of public works, where engineers have direct charge of the administration. They discover the principles that should apply, prepare the measures embodying the principles, and then administer the law when it has been enacted. Our hurried review of the history of India has left us in a prejudiced frame of mind. The Sepoy rebellion and the incidents leading up to this revolutionary outbreak,

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stand out like a spectre in the desert. We are satisfied that England should be condemned for its mistreatment of India during the two hundred and fifty years when administrative control was delegated to the British East India Company. We possibly forget that this company, through its engineering service, accomplished more for the real good of India than had been recorded in the entire history of that country prior to the ascendancy of English influence. Wise governmental principles have been introduced there and public service means something more than an opportunity for individuals to profit at public expense. When England assumed partial control of Egypt in 1882, experienced engineers from the Department of Public Works in India, were detailed to the Valley of the Nile, where they have made records in administrative work which we praise and admire. South Africa profited by the experience of both India and Egypt. The engineer is the right arm of the government in all of these countries. Family connections and political favoritism both give way to administrative experience and technical ability. Australia, that remarkable country which has already given us many splendid ideas as to good government, has gone even further. Representatives from Australia have studied the laws and administrations of all other countries. Its people have selected the best ideas of modern governments and then improved upon these. The Australian government represents its people. It is the best example of democratic government the world affords today. While we struggle along with the common law borrowed from England, Australia, an English colony, has abrogated that law wherever it conflicts with enlightened sentiment. The doctrine of riparian rights was cast aside without hesitation and something much superior substituted for it. This feature of the common law was eliminated without precipitating social or political revolution. The leaders were unselfish. They were concerned with problems of public interest; private claims which conflicted with these were given but little consideration, because in upholding public interest, private rights were all equally guarded, and there was no disposition to make public business a private business for a single profession.

We are not inclined to go to Spain in search of principles that we might apply at home. We are inclined to forget that Spain, almost alone among European powers, has retained the valuable features of Roman law, regardless of conquest by feudal tribes, the Arabs and the Moors. In the administration of resources that are naturally public, Spain can furnish examples in law and administration that we might well adopt.

When our government was organized, laws were needed before adequate legislative machinery could be provided for and placed on a working basis. Since the large majority of the people came from England it was natural that they should turn to the mother country for inspiration. Without realizing the danger of such a procedure, excepting as a temporary expedient, the common law of England was adopted by many of our states as a supplement to

statute law. Many principles were thereby introduced which belong to the past and which can only flourish under a government which still retains many of the basic features of the feudal system. Where the common law was accepted, the court was substituted, in part, for lawmaking bodies. Through this error on the part of our ancestors, the legal profession obtained an exclusive control of a very important branch of legislation and administration. The judiciary was given powers and responsibilities which were not anticipated in many of the state constitutions. In an address of Associate Justice Charles E. Hughes, of the United States Supreme Court, before the New York State Bar Association, in January, 1916, he made the following comments which are timely and from a source that commands respect:

> "There are two tendencies in legislation, here and there observable, which I cannot but think opposed to a proper conception of the functions of the courts. There is the tendency to assign to the courts administrative duties which do not belong to them and, sometimes, judges are denied appropriate authority.
>
> "Legislation of the first sort undoubtedly arises from distrust of powerful administrative agencies; it shows a desire to escape their authority and to have the judgment of judicial tribunals, with whose standards the public is familiar, in the final decision of difficult administrative problems. It seems to me to be the wrong way to reach the right result. The only reason for the creation of the new administrative instrumentalities—which appear to present government in a new phase—is the complexity of the facts with which government undertakes to deal and the necessity, if they are wisely dealt with, for the continuous and expert attention of a body exclusively concerned with the particular subject. To put upon the courts the burden of considering the details of administrative problems would be to overwhelm them; but for the courts to revise and rescind administrative action without competent and close study of all the pertinent facts would be not only to destroy the effectiveness of the administrative agencies but also to impair seriously the confidence reposed in judicial tribunals. It cannot be too strongly insisted that if we are to have these important administrative instrumentalities properly perform their duty, they should stand on their own footing, and that the public should realize that their safeguard is not in injecting the courts into the work of administration, to the confusion of both, but in maintaining an enlightened policy and in insisting upon proper standards of official conduct. The courts cannot be substituted for administrative agencies; nor. I believe, is it to the ultimate advantage of the community to divide between them the responsibility for purely administrative action."

Congress and our state legislatures are made up largely of lawyers. The legal fraternity represented in these law-making bodies doubtless reflects the "distrust of powerful administrative agencies," referred to by Justice Hughes. This "distrust" is so manifest, in many instances, that legislation providing for administrations which would relieve the court of much responsibility, dies a quiet death in obscure committee rooms. Where such measures finally receive the approval of the law-makers, the statutes are saturated with verbose legal phraseology which tires the average mind. Soon the meaning of the original law is altered by court interpretation and then the administrative officers begin to flounder in uncertainties.

Government should simply mean the transaction of public business. The English language is employed daily by most men in the transaction of private business. The newspapers, periodicals and the best of English prose and poetry do not have to be translated by a specially trained profession and then interpreted to the public. This was necessary a few hundred years ago when reading and writing were arts known to but few. At that time, also, the common law was developing and while people have advanced in a general knowledge of things written in their own language, the legal profession, in this land of the free, retains the monopoly that it enjoyed in medieval times. Honorable George Langley, Minister of Municipal Affairs, Saskatchewan, makes this comment:

> "In our case, we have no difficulty at all. The legislative authority makes its laws, and those laws are supreme over all, even over the constitution. In your case, your state legislatures make your laws, and a small-souled individual appeals to the court against the law, and a lawyer, in judicial office, of course, decides whether the law has any authority or whether it has not. I have discovered something that I did not know before. I have discovered that while we in Canada are ruled by popular will, our good friends in the United States are ruled by the legal profession."

A great corporation which would permit its rules and regulations to become impregnated with uncertain phraseology, abstruse statements and uncommon terminology, would quickly determine the source of the trouble and apply a remedy. We go on placidly with a lawyer at the head of the Department of the Interior, the only branch of government service which we might compare with the foreign departments of public works. Under this officer we find the Patent Office, the Reclamation Service, the Geological Survey, the Indian Service and the General Land Office. It is plain that the President does not need another lawyer in his cabinet. It would seem that an engineer, rather than a lawyer, should supervise these technical branches of public service. It is unnecessary to say that the same fundamental defect exists in other departments at Washington.

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Our state governments are suffering from kindred diseases. The common law of England is fairly well entrenched there. This is a state matter. The national government only recognizes the common law when a case, involving the same, goes to the federal courts. The common law gives the courts of the state authority to administer water resources, boundaries to land and similar subjects. The court is not only the judicial body, but it interprets (alters and extends) the common law and then administers the same, so that it has grasped a power that was probably not anticipated by those who were responsible for its introduction. Many features of the common law were not framed for the purpose of protecting people or for upholding public interests, but for the purpose of extending the power and authority of feudal land owners.

When an administration, which naturally demands the aid of technically trained men, is placed in the hands of those qualified only in the law, the work becomes legal rather than technical. Scientific considerations are largely ignored. In proof of this, read the leading court decisions on riparian boundaries, especially those cases which have to do with accretion and reliction. Nearly all other decisions, based on the common law doctrine are equally faulty, but the defects in reasoning and analysis are not all so glaring. In the meantime the public is losing ground each year and private investors are being imposed upon every day, because the principles now in effect belong to a decayed civilization. Let us refer to a few branches of public service which are recognized in nearly every other country.

Spain has accepted some responsibilities relative to the administration of water resources which are practically unknown in the eastern half of the United States. Among many commendable principles of Spanish law, we find the following:

> "The waters of rivers, whether navigable or not navigable, which of themselves or by junction with others follow their course into the sea, are not and cannot be private property, but belong to the public."

Water resources are naturally of a public character. This being so, the banks and beds of streams are public properties. Under the feudal doctrines of the common law of England the principle of public ownership is overshadowed by the theories which have been created by the courts to support and protect only the owners of riparian lands. The common law signifies legal control of a gift of Nature, while the Roman law and the statutes of all other countries, not influenced by the feudal system, demand an engineering administration.

We may find drainage laws on the staute books of many states. Drainage demands a knowledge of hydraulics, hydrography, hydrology, geology and surveying. Our drainage laws ignore these essentials and drainage is placed largely on a legal basis. The officers chosen to administer the law are usually selected without regard to fitness. The plans for drainage, such as they may be, finally

develop in a hap-hazard way under the stress of necessity, and errors in design, assessment of benefits and estimates of cost are never corrected, except where some engineering advice is accidentally obtained. The people concerned are imposed upon, poor works are constructed and no comprehensive drainage systems are realized.

The states have recently taken an active interest in highway work. State highway departments have been created. In order to leave the door open to those not having qualifications for the prescribed duties, the officers in charge are generally known as "highway commissioners" rather than highway engineers. Because of a lack of engineering advice the public has spent more money in highway work without receiving reward proportional to the outlay, than in any other branch of public enterprise.

Towns and cities are laid out without regard to public interests. Speculators in real estate do much of our city planning. There is but little competent supervision of maps and plats. As a matter of convenience some local county officer or officers, such as the prosecuting attorney or judge of probate, may look them over to see that all t's are crossed. The plats then go to some equally well qualified officer of the city administration, who forwards them to the state auditor general for final acceptance. From the time they leave the surveyor until they are approved by the state, they receive inspection from no one who can even check a traverse computation. Washington, our only city having a real plan, was laid out by an engineer. The example is worthy of general study. Our towns and cities are growing like Topsy and in time they will have to be largely rebuilt at public expense. Many of the large cities of Germany have passed through this trying ordeal during the last thirty years.

The National Government has bequeathed us a comedy of errors in its public land surveys. These were conducted in an atmosphere where politics always dominated science. Realizing that accurate measurements, whether lineal or angular, could not be anticipated under such a system, a law was passed by Congress which states that the measurements returned by the surveyors shall "be held and considered the true length thereof." Lands taken up by settlers may contain a few acres, more or less, than the patents thereto disclose. Settlers may lose from two to ten acres because of this kind of public surveying. They are then required to donate lands for highway purposes. They continue to pay taxes on the entire area specified by the patent. In some cases they pay taxes on areas covered by water, which is naturally public property, and which can never produce revenue. The states have a responsibility here that they should meet. Distances can be measured. Let us admit this fundamental consideration.

Public utilities should be valued by engineers in the employ of the state. Their findings should be authoritative. No appeal

should lie except where it could be shown that there had been an abuse of administrative authority.

Public safety is insured under an engineering administration. The pollution of streams and lakes is a matter in which the public should be concerned. Under the doctrine of riparian rights, only those who own lands bordering on streams and lakes, seem to have any claim for protection of this kind. People are killed each year because of the absence of steam boiler inspection. Dangerous railway crossings continue to gather their toll of human life. High tension electric transmission has added a new element of danger. The state should be concerned in the equipment and regular inspection of life-saving devices at every public bathing beach. There are many dangerous bridges. When lives are sacrificed because of a lack of caution on the part of the public, there may be a brief discussion of causes and remedies; there may be a suit for damages. The matter is soon dropped and interest is not resumed until another fatality records the tendency of man to accept private risk rather than to encourage public responsibility.

The terms "engineer" and "engineering" must soon be defined by law. The engineer may have a profession, but he has no well-defined field of service or activity. Some qualifications are prescribed for practice in other professions. Any person who possesses sufficient self-assurance may call himself an engineer and employers cannot discriminate, because they cannot judge of the quality of the service performed. The barber, brick-layer and the plumber have definite fields of activity,—not so the engineer. Various kinds of work that he has claimed for many years are being taken from him by professions that are already recognized under the law and by others who have no professional qualifications.

A state, to survive, must ultimately mean more to the people than a policeman and a tax-gatherer. In behalf of the public and in support of a government such as ours, which easily falls a prey to an element which displays but few altruistic tendencies, the engineer must become a factor in the business of the nation. He has more to say to the people of the country, in so far as the real interest of the individual and the public are concerned, than have the members of any other profession. To accomplish this duty he must perfect himself in those arts which have given men of other professions an advantage over him in the past. The engineer has led the way in countries that have an almost despotic form of government. He will not fail here, where his task lies in his own community, and where his associates will give ear when he begins to exhibit an interest in public affairs. His trial will come when he is placed in responsible charge of some department of public service. The temptation to accept employment under private enterprise will come to him. He will be told that it is possible for a great engineer to serve two masters. He will hear the alluring song of the political siren, enticing him to wreck the personnel of his department, before many of the

important principles relating to his work have been identified and embodied in the law. His hopes and aspirations may seem to be blighted for a time by a court decision which destroys important features of legislation governing his work. He should anticipate this. He should understand that the courts lag behind in the dust of the wheels of progress and that their errors simply afford him another opportunity to grow in the sight of a public that will finally become appreciative.

Our quarrel is not with the lawyer or the courts,—it is with the system that thrusts public business on a single profession, and a profession which goes backward rather than forward for its ideas and inspiration. The courts have protested many times as new responsibilities and new administrative duties have been placed upon them. The legal fraternity furnishes the best examples of public spirit to be found. The lawyer and the court have welcomed reforms in government. The engineer is the man who has been asleep at the switch. The expert in law will never discover technical administrations in other countries. It is not necessary for him to know much about statute law beyond the borders of his own state. The engineer of today has a greater responsibility in matters of government than has the lawyer, because his field of public service lies unexplored and almost forgotten.

DISCUSSION.

L. K. Sherman, M. W. S. E.: Professor Johnston has presented an unusual type of paper for an engineering society. I hope that there will be more of such papers. The engineer has been asleep at the switch, as he says. I think he is beginning to wake up, however. The last few years have witnessed a remarkable change in the activities of the engineer in the public service. It is a healthy evolution, and we ought to take up more questions of this character.

In general, I agree with the opinions of Professor Johnston, but when we seek to remedy an evil, it is a good thing to look around and see that the remedy is not worse than the disease. So far as efficiency in public service is concerned, probably the most efficient form of government would be an intelligent, wise and benevolent despotism. The objection to that form of government, however, is that there can be no assurance that this wise and benevolent despotism will continue.

When we review the history of nations away back from the time of Solomon, and down to the present time, this fact stands out in prominence, there is no aristocracy of birth, profession, education or inheritance. The leaders selected by the people, even where they have selected them from the mule drivers on the canals of Ohio, or from the rail-splitters in Illinois, never were excelled in wisdom, ability or in judgment by any of those specially trained monarchs who held their job because, as they say, "God gave it to them."

I am not clear about the author's criticism as to efficiency in the case of a government by democracy. He has brought out some

pretty severe arraignments, and a good many of them are true, but we have been prone, all of us, to go forth in criticism, for it is a good deal easier to criticize than it is to build up or go into constructive effort.

We have criticized the management of public affairs. I have heard the Public Works Department of the City of Chicago criticized by comparison with certain railroad companies. Now, it happened that there was a case that I knew something about. I used to be employed by the Santa Fe Railroad, and afterward by the Pennsylvania Company. I have never been employed by the city of Chicago, but it has been my fortune to be well acquainted with the Department of Public Works in the City of Chicago. And this I know, that the Department of Public Works in the City of Chicago has been, and I believe is today, more efficient in the operation of their construction departments, and in other departments of public work, than is the operation of these great railroad corporations.

One statement in the paper referred to the Honorable George Langley, of Saskatchewan, who says: "The legislative authority makes its laws, and those laws are supreme over all, even over the constitution." I am glad that Mr. Langley is satisfied with that law as he represents it to be in that condition. But I thank our forefathers that over in this country we do not have any chance for a legislature to make a law than can override the Constitution. You know what the Constitution is, that it is the Bill of Rights that says just how far a majority can go in the legislature in making law when they happen to be in power at any particular time.

About the drainage law: That is a subject that I have gone into to some extent. The drainage law is a heterogeneous mass that has gradually grown up as the country has developed, and it has been patched up and additions made to it. And when you look at it it looks bad. It looks as though the best thing you could do would be to wipe it off the slate and start anew.

About two years ago the Illinois Society of Engineers and Surveyors thought that way, and they appointed a special committee to go over all the drainage laws—and there is not any association of more competent drainage engineers than are in that society. They reviewed it the next year and the year after, and reported that they were against changing the law. It was a case of getting out of the frying pan into the fire. In other words, this law had been developed and had been tested in the courts, and threshed out so that they knew just about what would hold in the Supreme Court and what would not. They felt that if it were wiped out and they began all over again they would not know what was law, until after further litigation and decisions of the Supreme Court. Consequently, their recommendation was that the law should not be discarded, but certain amendments should be made. I agree with the author's criticism of the common law relative to riparian rights. The law in Illinois is quite definite as regards lakes, but needs careful attention by public officials to preserve public interests in the case of rivers.

The author speaks of the relation between the judicial and the executive or administrative departments. I would infer that he was opposed to any mingling of such administrative duties. Personally I cannot see why there should be much objection. The city council, for instance, is partly legislative and partly administrative. The commission form of government is still more so. Take any of the commissions, and they are decidedly a mixture of administrative and judicial. I fail to see much objection to this.

I will give you a little illustration of a case in which it worked out well to have them together. This was a case of the State of Illinois vs. Spring Lake Drainage District. That went on through the courts for eight or ten years. It finally went clear up to the Supreme Court, and the findings were sustained. These findings were drafted by our friends, the lawyers, and they stipulated what the elevation of the waters should be, and how wide the canal should be, and where the levees should be, and where the locks should be, and all those things. After they got through with it the Supreme Court said it was all right, but neither party was satisfied with it because it did not mean anything. It was an absolute impossibility—there were figures that conflicted, and the result was that both parties got together and they said, "Here, this doesn't suit either of us. We have fought for ten years, and got it through the Supreme Court, and it doesn't suit either of us." And they took it before a commission that, while judicial to a certain extent, was also administrative. It had engineering ability and was informed in that particular line of work. And before that commission a scheme was outlined which was agreed upon by both parties, that has been adopted and carried out, and both parties are satisfied.

H. J. Burt, M. W. S. E.: The ideas presented in the paper seem rather startling to me. They attribute so much to our legal friends, and so little to our profession. I have always given the engineering profession credit for having held its own in its work. I believe that it is very generally recognized as being an important profession, and that its work is looked upon as being of a high character. I realize, of course, that there is a great deal more that we can do, and deem it to be the duty of engineers to take part in the discussion and conduct of public affairs, and to help shape legislation so that public works will be authorized in a proper way.

W. W. DeBerard, M. W. S. E.: We have listened to a very, very interesting paper, and a severe arraignment of the engineering profession, it strikes me; but we have not heard a word as to how we are going to get into public service. We have heard an arraignment of those who are in the public service, but not very much of how the rest of us can help those who are in that service now. It strikes me that Professor Johnston, after telling us of these ills, should have at least two or three or four paragraphs at the end to tell us his idea of how the matter could be bettered. He told us about the ills, but he did not tell us anything very definite as to how you and I are going to help this proposition out tomorrow, what we are going to

do tomorrow, what we are going to do tonight, what we are going to say to our fellow members as we go home on the car. And that is the thing that I like to get down to, what are you going to do next about a proposition?

I don't know that I have any ideas as to how the thing can be solved. It is a question that is not easily solved, and one that a great many of us have thought about a long time. It is a thing that is very dear to the hearts of some of us, how we can increase the value of the profession to the world at large.

Every man has back in his head somewhere an altruistic idea that his profession, the thing that he is doing, is the thing that is helping the world to be a better world, and to help his city and state and government to be the best in the world. I think there are very few engineers who are so selfish as not to have those thoughts quite frequently.

Now, just how to go about getting that idea into expression, into action, is certainly a problem. Can this Society, as a society, do anything along that line? It seems to me that it can. And there is one thing, I might mention the fact, that last week President Grant announced that this organization had become a member of the Chicago Association of Commerce. That expressed in a great measure the fact that we, as an organization, are trying to mix up, so to speak, with business and politics, with things which have to do with the civic betterment of the city.

Now, there are a large number of things that this Society, as an organization, might do, certain activities it might enter into that would help along the lines which are criticized there.

Mr. Sherman spoke about the work of the Illinois Society of Engineers. This society has done certain work along that line which might be mentioned very aptly. There are other things. I think we ought to hear from a number of the men here as to those other things that can be done, and that we might be doing right now. Let us get started on them in a hurry. If the things are as bad as pictured, why, we ought to get busy in a hurry.

J. W. Lowell, Jr., ASSOC. W. S. E.: It is my belief that a great many engineers stand in the path of their own progress and that they also obstruct the progress of the entire profession.

I have observed that generally engineers fail to impress upon or convince their clients or employers of the value of their services. For instance, an engineer designs a structure and makes a charge of perhaps 5 per cent of the estimate cost of that structure. The engineer's fee is then placed in an obscure position at the bottom of the estimate which is presented to the employer. The employer studies the estimate and notices the item, "engineering charge, 5 per cent," and since the engineer states that this is a charge or liability, the employer accepts it as such.

By this procedure, as I have said before, the engineer has injured himself and his profession, because he has led his employer to place his services on the wrong side of the ledger. Would it not be

a step forward if the engineer would point out to his employer that he is saving money for him and that instead of being a liability he is really an asset?

The way in which the engineer charges for his services today actually results in better compensation for inferior service, because basing the compensation as a percentage of the cost, it is proportional to the cost. An employer would rather employ better and higher salaried men if they would effect greater economy.

It is generally true that an engineering organization, if held together year after year, will increase in efficiency and that each man will become more valuable. Then why should not the salaries of the individuals making up such an organization increase proportionally. I believe that employers could easily be induced to raise salaries and appropriations for engineering service if the chief engineer would makes it a point to show the men who control the purse strings the value of the service they are getting.

It seems, however, that chief engineers often are inclined to forget the obligation they owe to the men under them. By doing this they not only harm their profession, but also themselves, because the compensation of the chief depends to a large extent on the compensation of his assistants.

The engineer who commercializes his profession and becomes a salesman or promoter is generally paid far better for his services than is his brother, the strictly technical engineer. Why? Because he puts himself upon the right side of the ledger by becoming a creator of profits.

Is it not fair to assume that the strictly technical engineer would also command better remuneration if he would impress his employer with the fact that he, too, is a source of profits, rather than an item of expense?

Carter H. Lamb: Professor Johnston, in his paper, indicates that, as engineers, we must have a lawyer at our right hand to do our talking and to see that we sign our names in the right place on the legal papers, and to fight our battles in the courts. We have found them, no doubt, very handy.

There are one or two suggestions, however, that perhaps we could put in force, not to get away from the lawyers entirely, but to put ourselves forward a little more, for in their capacity of talkers for the engineers, they are the ones, as Professor Johnston indicates, that are in the public eye.

The first suggestion would be, that perhaps a little more law could be given to the engineer in the universities. I believe, if I remember correctly, in the university there was one course on contracts and specifications. And, as I remember, that was optional; at least, I don't remember ever taking it. It seems to me that more contract and specification courses, and business law courses in college would help us to stand clear of the lawyer when we get into engineering practice.

The other point is that after we are out of college, not to con-

tinue our study along the line of engineering entirely, as we are so apt to do and become specialists in some particular line, but to broaden out and to try to read and understand and perhaps talk the language that seems to be peculiar to the lawyer, so that, perhaps, in that way, we may be able to push ahead a little more strongly and show that the works that the engineers are accomplishing are not accomplished because of the greatness of the right hand man that we have by us, but because of the men who are actually doing the work, the engineers.

H. H. Stock, M. W. S. E.: During this coming year might not more attention be given to the matter of appointments on state and city commissions? I cannot speak for Chicago, but according to the reports of the Illinois Economy and Efficiency Commission there are something over a hundred commissions in the State of Illinois.

Many of those commissions vitally affect engineering projects and engineers. I wonder how many names of engineers are presented to the governor for appointment on such commissions—unless it is something that vitally affects a society such as this.

The Economy and Efficiency Commission which had to consider the efficiency of the entire State government had no engineer on it. If there is any body of men who have been prominent in the efficiency movement it certainly has been the engineers. This coming winter there probably will be a large number of commissions to be appointed. And might not such societies as the Western Society pay attention to such commissions as are authorized, and try to get appointments on them of men who would really represent the engineering bodies of the State?

E. N. Layfield, M. W. S. E.: I would like to say in that line of thought, when the Board of Examiners of Structural Engineers was appointed by the present governor, under the law that was passed last year, every member of the board was taken from a list that was furnished the governor by the Western Society of Engineers.

Chairman Roper: Professor Johnston in his paper endeavored to lay a few of the facts on the table, which, as the Chairman considers, is one of the starting points in arriving at correct conclusions. He also has taken occasion to remind the engineers of a few of their faults and short-comings, possibly with the idea that if they were set forth, they would give a few points of attack. And apparently from the constructive suggestions which have come out in the defense of the engineers this evening, it indicates that he has started some of the engineers to thinking along right lines. I think some of these constructive suggestions will bear fruit.

John Stone: I was just wondering whether this Society has ever affiliated itself in any way with the Civic League of Chicago. As I understand, the Civic League was organized for the betterment of social conditions about the city. And if we could in some way give it our support I am sure that it would be a very wise thing, and a beneficial thing to do.

Murray Blanchard, M. W. S. E.: I think that Professor John-

ston has brought out a good many points in a line of which he has made quite a specialty and in which he is very competent to criticize. The problems are there, and it is only by stirring up these matters and bringing them before the engineering profession that they can be rectified. And sometimes it does good to bring them up for discussion.

In the government service at the present time the principal engineering work is in charge of the Army Corps, and there is very little opportunity for the civilian engineer to get ahead. He gets into the civil service and he can go just so far. This is a criticism of conditions which I observed when in the service. The only chance that we have to rectify the existing conditions is through the legislature. Very often there are prominent engineers brought into the government service who have done great work, and very notably is the late Alfred Noble. He worked for a great many years for a very small salary. And not until he left the government service and went with a large corporation was he able to command a salary that an engineer of his ability ought to have. And that is one of the reasons why more engineers do not go into the government service.

I think that papers of this kind get the engineers to thinking where they stand, and the discussion helps to get them to working together for their own good.

J. L. Jacobs: As a non-member, I can with grace, compliment the Western Society on the positive work which it has started out to do relative to interesting and informing engineers on the problems, workings and opportunities in the public service.

Without in anyway detracting from the value of the work which has been started, the Western Society, and the engineering profession generally, have greater opportunities and duties before them in the development of civic interest and constructive action on those public questions, the proper solution of which will spell more effective governmental administration.

The results of the achievements which our engineers have accomplished in the public service are great and far reaching. No defense is necessary for the work and achievements already accomplished. What is necessary is concerted positive action of the engineering societies and individuals in interesting our trained and technical groups on the questions and matters of public administration and governmental politics. The trouble is that so small a portion of our engineers are interested, or giving a proper share of their time and thoughts to questions and problems before our governmental bodies.

The author of the paper has brought out clearly what the men in the legal profession have and are doing in these respects. They have been right in the midst and are considered as prime factors in the development of the public service. The legal profession should be complimented and commended for the public interest and good results brought about by their efforts.

There is every reason why the engineering profession should

take greater interest and become a directing factor in planning, studying and solving the problems confronting the various governmental divisions and in aiding the development of better social, economic and industrial conditions in this country.

It is not necessary here to cite the increasing number and the growing importance of activities and services which have been taken over by public administrators. Analysis of the budgets of our municipalities and other governmental units discloses the increases and the complexity and technical character of public problems and indicates also the increasing opportunities for trained men and women in the public services.

It seems to me that the problem before the engineering profession, as well as other groups who have at heart the development of effective and responsible democratic government, is to furnish active support for popularizing the principles of and promoting sound measures for responsible and responsive government. Consideration by the engineering profession—by the organized membership of the engineering societies, a membership which comprises between 30,000 and 40,000 engineers—of constructive politics and the problems of public service administration, would have the effect of broadening the active constituency of our citizenry and improving and perfecting the instruments of our democratic government. The decision and attitude on any of the problems by such groups would also have great weight with other groups and the individual citizen.

Development of more effective and economical governmental administration and opportunities for technical and trained personnel in the public service, requires concerted action and support of the trained citizenry. It is up to the engineers individually and collectively, to step right in and aid in the solution of these civic and social problems, as they have so well done in industrial affairs.

The question which naturally arises in the mind of each man is how he is to go about it and what problem should first be tackled. It would be difficult in the short time to state the number of ways in which the individual engineer could, through his efforts and interest, do some good for the public service, but there are a number of pertinent matters which I believe we will all agree require the attention and backing of the engineering profession.

There are questions and measures which have to do with eliminating confusion and providing for responsive and responsible governmental administration and system. These matters include such matters as the decrease in size of our legislative bodies, the executive budget, the reorganization of our governmental bodies, extension of positive civil service administration, divorce of politics from administration.

Support and insistence by the engineering groups for such constructive policies would have great influence in governmental affairs, on legislative representatives and on public administrators. Demand for the absolute divorce of politics from public administration through these powerful forces would have the effect of clearing the

atmosphere with reference to this vital problem and thus make for more effective and economical government.

The success of a business or industry is largely dependent on the character, ability and treatment of the human element. This has not been fully recognized in the public service. Except for the negative movement in preventing spoils through elementary civil service administration, comparatively little has been done or accomplished with reference to making the public service a profession sought for by trained men and women.

The call of technically trained and experienced men and women for the public service has now become so urgent that action must be taken for broad positive employment administration. The movement which started within the last ten years in a number of our larger cities for constructive reorganization of employment control has borne fruit and is growing. It is one of the signs of the opportunities which are in store for the development of a more permanent and efficient personnel in the other municipalities and states, and in the federal government.

The engineer is most concerned in this employment problem. Insufficient study and recognition has been given to the matter of educational and experience requirements in the ever-increasing technical positions in the public services. A large number of positions which require technical training, knowledge and experience are now either filled by non-technical or "spoils" employes, or are so set up as to be uninviting to ambitious and trained men.

Our engineering societies have been concerned for a number of years in setting up specifications and standards for materials, equipment and constructions. Little or nothing has been done or accomplished by them with reference to the setting up of guides or standards for technical personal services. These are particularly necessary in the public service, where conditions of employment are such as demand definite standards, if trained men and women are to be interested and if we are to have more effective and economical administration.

Support of the principle and the preparation by our engineering societies of standards and specifications of work requirements and qualifications of training and experience for the large number of engineering positions in the public service, would have the effect of showing up for the first time, the necessity of, and opportunities for professionally trained men, and would have the further effect of interesting a larger number of engineers to enter and remain in the public service. Provision of definite standards with fair and equitable bases of compensation would also have the effect of establishing positive public employment methods and control and give to employes prestige and careers in the public service.

This problem of providing positive employment control is staring our municipalities and other governmental bodies squarely in the face. Here is a clear duty of the engineering profession and societies. They and they alone can undertake the task of the standard-

ization of technical public employments and aid in the development of a more permanent and efficient personell in the public service.

Something positive and specific can be taken hold by this Society at this time. Let us consider the local employment situations in the Chicago city government and the Sanitary District. There are positions in both services, the duties and responsibilities of which require engineering training and experience. Why cannot this Society keep continually after the officials to see that the principles of positive employment are adhered to and that the methods used in recruiting and promoting the employes are based on accepted principles of business management.

I understand there are right now some thirty-five examinations called for different positions in the Chicago city service. These positions pay salaries up to and including $5,000 a year. I understand, too, from an article in the newspaper the other day, that there were not a sufficient number of applicants for the position of city superintendent of streets, which position pays a salary of $5,000. There is every reason why this Society should get after this matter and find out what is the actual cause and solution of this. Qualified men, of whom there are a number in this city and elsewhere, would gladly come and take the civil service examination for such a position if they knew of the support and vigilance of a society of this kind on these civil service matters. This is something that this Society can do right now.

The time is fast approaching, too, when the local city council is to begin its deliberations on the allotment of some $40,000,000 for carrying on work and activities by the city departments during the next year. I dare say that more than half of that amount is to be appropriated for engineering or semi-engineering improvements. This Society should see that sufficient provision is made for engineering organizations to take care of engineering matters. It should also continually keep its eyes on the doings over there. The influence and vigilance of a society of this kind on the acts and results accomplished in the various engineering units would have a very healthy effect.

These are things this Society can do. They are small matters, but if taken hold of as they arise, there is bound to be improvement. Such improvements are cumulative.

I could talk indefinitely on other matters that might be accomplished. But I think if the Society would take hold and look after a number of these propositions and report on accomplishments, say in a year's time, this Society will have done more than any other engineering society has done in the past.

CLOSURE.

Professor Johnston: When we speak of the engineer and his place in government, some statements are likely to be made which need qualification. The writer believes that the engineer is to accept his full responsibility as a citizen. He is, therefore, an optimist. In

many respects, our government is the best that has thus far been produced. We all have the utmost confidence in a democracy. While it was not an engineer who said, "eternal vigilance is the price of liberty," yet we may accept the sentiment thereby expressed without reserve.

The writer has spent his allotted time in public service. He has held office and has been under fire for years while trying to uphold some of the principles that are referred to briefly in the paper. He has had his troubles with politicians, law-making bodies, lawyers and courts. Throughout this period, he was always able to secure a hearing and when he failed to obtain support, he was largely responsible. He knew, or thought he knew, what principles should be incorporated into the law. At first he did not know how to enlist support for them. One cannot go to a legislature and secure legislation which provides for radical change unless public sentiment is favorable thereto. Engineers know of no formula which concerns public sentiment, either as a variable or a constant, and no slide rule has thus far been perfected which is helpful in problems of this kind. Engineers deal with certainties, to a large extent. It did not occur to the writer, when he first advocated a better government of water resources, that it would be possible to deal with the people vitally interested. He found, after some years of bitter experience, that this is the easy way and the right way.

When an engineer finds the principles that should apply, he will have plenty of supporters following a brief effort to convince the public of their value. The law-maker and the court rapidly change front when people begin to manifest an interest in principles. The engineer who is able to convince the public as to the wisdom of his plans need not worry greatly about the politician. He develops what we commonly call political strength as a by-product from his campaign. While this is incidental, yet its importance should not be overlooked. It gives the man, who has the courage to enter the contest, an opportunity to fully demonstrate the wisdom of his policies in the administration that is to follow. He need not worry about the personnel of the administration. If he is not the leading executive officer, representing the public that supports him, he will be the "power behind the throne."

While it would be pleasing to engineers to have their brethren occupy many high positions in government, the paper under discussion relates exclusively to those places which have to do with technical public service. The history of the past is likely to be repeated, and if the supply of timber permits, other rail-splitters may reside in the White House. We may have another engineer, like Washington, at the head of our national government. We may have carpenters and plumbers in the cabinet, and congress may be made up of farmers and merchants. Regardless of the future of these branches of our government, we will never have a grocer or an engineer among the judges of the Supreme Court of the United States. We do have lawyers, railway employes and hack drivers filling the important offices of United States Surveyors General. Who is to

protest against this practice? Who would protest, should a druggist be appointed as judge of the United States Circuit Court? The general public would not be much concerned. However, we know that the legal profession would see to it that only a trained man from their ranks should be considered. Should a janitor be given a place on the state board of health, the physicians of the state would create such a disturbance that an immediate change would be made. A little study will demonstrate that no reform has ever taken place in any branch of public service which concerns a particular profession until the members of that profession have taken an active interest in policies which protect the public and in a secondary way, protect the profession itself.

The writer has a government report before him which concerns an investigation of some legislation in a neighboring state. The author of the report, an engineer, admits that the laws embraced in his study are very defective. They are not supported by the principles that should underlie such legislation in a fundamental way. However, the statutes in force have been so thoroughly tried out in the courts that he recommends that no material change be made. He overlooks the fact that when good laws are enacted and an able administration provided, litigation terminates. Litigation is common in many fields of public service which concern the engineer because the underlying principles are not applied. The work goes to the court where the lawyer is supreme and no change will take place until the engineer begins to preach the gospel of efficient and capable government in the fields which concern him. This is not simply an untried theory, because the writer has been able to carry it into practice in a humble way. He has seen other engineers accomplish reforms so far-reaching that this generation cannot fully grasp their extent and significance. The majority of people are ready to accept the new, providing real merit is demonstrated. The history of man consists largely of a recital of his struggles to overcome pernicious doctrines. Frequently, these doctrines have been upheld by the courts long after public opinion has decreed their abrogation. Salem witchcraft and slavery were both upheld by the courts, but they have long since gone into the national waste basket.

While our friends in Canada seem to have been careless regarding a constitution, we may admit that we prefer a constitutional form of government. The people of the country are able to alter constitutional provisions. Most of them can read the constitution and some of them can understand it. Our laws are presumed to be framed and enacted in response to public demand. However, the common law as accepted, modified and administered, is largely independent of popular control. Without discussing the common law in general, we must admit that its application to modern problems, involving branches of science that were unknown during the period which witnessed the development of that law, is absolutely unnecessary, if not dangerous.

The writer has already intimated how an engineer may make his influence felt. Every paper and every magazine is demanding

copy. The man with ideas always has an opportunity to be heard. Presume that an engineer is interested in the subject of drainage. He can easily obtain all of the important legislation on the subject available in this country. As he reads the various statutes relating to drainage he will discover that proceedure varies under the laws of the different states. He soon becomes able to judge between good and bad legislation. He may obtain some ideas that appeal to him. He then extends his investigation to foreign countries. He knows that the Delta in Egypt offers great opportunities, providing the land can be effectually drained. He assumes that there must be drainage laws and a drainage administration in Egypt. His study continues until he becomes informed as to the practice of drainage in the civilized countries of the world. When an engineer has thus informed himself, his advice and his services will be in demand and he will find some difficulty escaping a leadership, assuming he should wish to do so. When such an authority arises among engineers his brethren of the profession should be the first to support him.

It is suggested that engineering courses in our universities might be modified so that the young man, upon leaving his alma mater, might become a small wheel in the machinery of government while performing another service in the field of his profession. This is a good suggestion. However, courses in contracts, wills, torts and conveyancing simply add to his technical training. With these alone, added to his engineering work, he would still be a hired man, although, possibly, of a slightly different grade. The young engineer should understand government and the principles that underlie government. He should be particularly well informed regarding the engineering work of other countries and the principles which support technical administrations there. He should be able to write and to speak in public. It would seem that the time has come when our engineering schools might appropriately offer courses which would equip the young engineer to take an active part in support of public work of an engineering nature.

The writer is acquainted with many engineers in public service. They represent a splendid type of citizenship. They sacrifice much in the way of compensation. They merit our support. Conditions will change when the engineer selects the principles which are to govern their work.

It is difficult to discuss the subject before us without arousing the feeling that we are hostile to the legal profession. We are only hostile to some obsolete principles of government. It is possible that there is a lack of mutual respect between the two professions. When our attitude towards our own field of public service becomes positive, we will have more respect for ourselves and probably the lawyer will have more respect for us and for our opinions.

The writer is appreciative of the kindly consideration accorded his paper. The discussions have been to the point and a spirit of tolerance has been manifest throughout, thus demonstrating that even a great American engineering society represents democracy rather than benevolent despotism.

November, 1916

CONSTRUCTION OF A NARROW GAUGE RAILWAY IN THE REPUBLIC OF PANAMA

By Aaron S. Zinn, M. W. S. E.

Presented November 6, 1916.

In this paper, on the "Construction of a Narrow Gauge Railway in the Republic of Panama," I do not expect to present anything new to railroad engineers, as far as the theoretical part of railroad engineering is concerned, but a number of things in connection with its history and certain features in the contract and construction may possibly be new and interesting to the members of this Society.

This railway, which is 200 miles west of the Panama Canal, was named the Chiriqui Railway because of its location in a Province of the Republic of Panama by that name.

A railway through the Republic of Panama first became a project of national importance at the time Col. Wm. F. Shunk made a survey through that Republic for the widely discussed Intercontinental Railroad from Mexico to Buenos Aires in 1893. Soon after the separation from Columbia and the creation of the Republic of Panama in November, 1903, various railroad projects were discussed by the several succeeding governments and legislation enacted authorizing the executive power to undertake certain projects. In 1910 a survey for a narrow gauge railway was made for the Republic of Panama from Panama City to David, a distance of 200 miles. This survey, profiles, maps and estimates were made under the direction of Captain Fred Mears, Chief Engineer of the Panama Railroad. The estimated cost was about ten million dollars. The project was abandoned and nothing more was done until after Doctor Belisario Porras was elected President in 1912. It was the opinion of President Porras and his advisers that the practical way to develop the best part of the Republic would be to construct a railroad from Pedregal, on the Pacific Coast, to David, the capital of Chiriqui Province, with branch lines to La Concepcion, Potrerillos and Boquete.

The country around La Concepcion is rich in the production of bananas, sugar and tobacco. The llanos (prairies) along the line of railroad resembling somewhat our western prairies produce not only rice, corn and all kinds of tropical fruits, but it is first class pasture land where thousands of horses and cattle are raised with very little trouble and expense.

The country around Boquete, at an elevation of 4,000 to 6,000 feet above sea level, produces as good a grade of coffee as any place in the world, with about twenty large plantations under cultivation. With a few exceptions the inhabitants of the province outside of the leading towns are Indians and a mixture between the Indian and Spanish. They are not progressive and they discour-

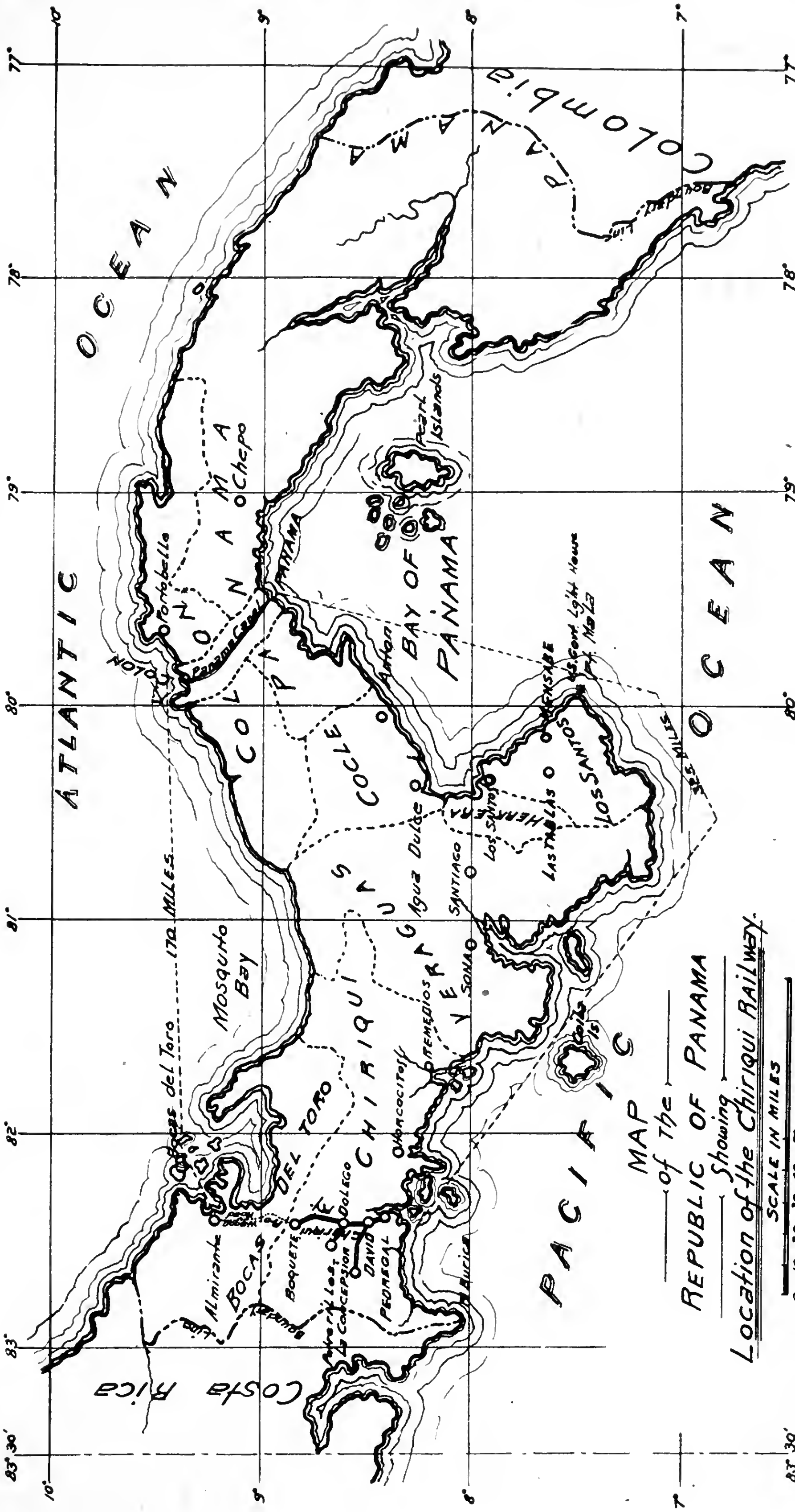
MAP
of the
REPUBLIC OF PANAMA
Showing
Location of the Chiriqui Railway.
SCALE IN MILES
0 10 20 30 40 50 100
A.S. Zinn - Consulting Engr.
ATLANTIC OCEAN
PACIFIC OCEAN
BAY OF PANAMA
Colombia
Costa Rica
COLON
PANAMA
COCLE
VERAGUAS
HERRERA
LOS SANTOS
CHIRIQUI
BOCAS DEL TORO
Mosquito Bay
Pearl Islands
Portobello
Panama Canal
Chepo
Anton
Agua Dulce
Santiago
Sonao
Remedios
Horconcitos
Dolega
Boquete
David
Pedregal
Almirante
Las Tablas
170 MILES
325 MILES

Fig. 1.

age any modern improvements and it was believed that a well equipped railroad would be a solution of the problem of inducing a better class of people to settle in the country and develop its resources.

Maps, profiles and estimates for railroads in three of the most important provinces were submitted to the Government, after extensive surveys had been made by experienced American railroad engineers.

The President of the Republic submitted the plans and estimates of the Chiriqui project to a Board of Engineers appointed by Col. (now Major General) Geo. W. Goethals, Chief Engineer of the Panama Canal. This Board of Engineers consisted of Captain R. E. Wood, Captain W. H. Rose and A. S. Zinn, all of the Panama Canal. The Board reported unanimously in favor of the

Fig. 2. Hand Excavation with 2 ft. Gauge Track and 1 yd. Dump Cars Pushed by Hand.

construction of the Chiriqui narrow (3 ft.) gauge railway, later called "Ferrocarril Nacional de Chiriqui" (National Railway of Chiriqui). By recommendaton of Colonel Goethals, the Government of Panama appointed the writer Consulting Engineer on all public work, the principal work being the construction of the Chiriqui Railway. Specifications for the construction were prepared and in February, 1914, the contract was let to W. R. Hebard & Company for the engineering and complete construction and equipment of the railway, ready to operate; all plans, pay rolls, equipment, construction, etc., to be approved by the Consulting Engineer.

As the Government had very little money in its treasury, the President was authorized to negotiate a bond issue abroad to such an amount as would be necessary to complete the railroad. The

approval of the State Department at Washington was secured and negotiations were eventually concluded for the sale of the 30-year 5% Republic of Panama bonds at a good price.

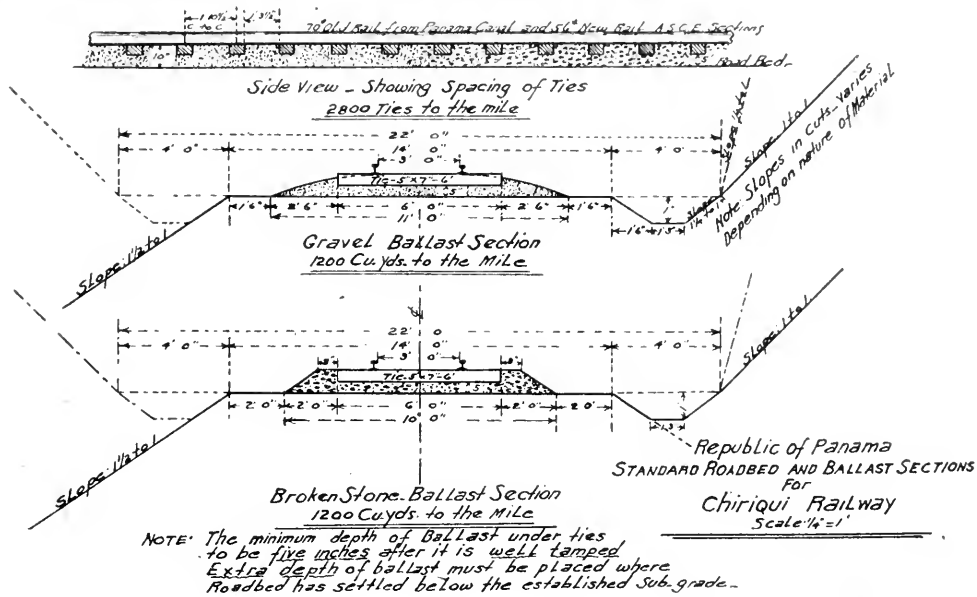

Fig. 3.

The construction work was started in April, 1914, and carried on slowly for seven months at the entire expense of the contractors on account of the delay in financing the project, the Government

Fig. 4. Typical 72 in. Reinforced. Corrugated Iron Pipe Culvert.

not being able to secure any money on the bond transaction until November, 1914. The work was then continued with a much larger

force of men and the best available construction equipment, consisting of two second-hand 18-ton saddle tank type locomotives from the Panama Canal, two new 87-ton consolidation type locomotives, one pile driver, one 70-ton steam shovel, one wrecking crane, 12 dump cars, 20 flat cars. 75 one- yd. hand dump cars with 8,000 ft. of two ft. gauge track, six section cars, three motor cars, etc. All construction equipment to belong to the Government on completion of the work according to contract. Most of the excavation, amounting to 410,223 cubic yards, was done by hand with the use of the one-yard steel dump cars pushed by hand on two-foot guage tracks that could be quickly laid and shifted to any position required. This method of handling material from narrow cuts and short haul

Fig. 5. Bridge Over Rio Chirigaugua La Concepcion Line.

fills was found to be an economical method in handling a large quantity of material in connection with the Panama Canal work and is popular with all contractors doing work in the tropics where they have to contend with a great deal of rain and mud, native and Jamaican laborers being employed at a certain price per car. Grading with teams and scrapers is very seldom done, as it has proved to be slow and expensive. The steam shovel was only used to load the gravel for ballast. The total length of main lines exclusive of side tracks is 57 miles. On the line to La Conception, a distance of 18 miles, the maximum grade is 3% and the maximum curvature 6 degrees. On the line to Boquete of 32 miles the maximum grade is 5% and the maximum curvature 12 degrees.

In climbing the slopes leading up to the mountains around Boquete for a distance of nine miles the average grade is 4.2% and the maximum curvature 5 degrees.

On the Potrerillos seven mile spur track the maximum grade is 5% and the maximum curvature 5 degrees.

The consolidation type engines purchased were guaranteed to haul 120 tons behind the tender, up a 5½% grade, at a speed of 10 miles per hour. It was found by actual test that one of these engines hauled 150 tons at a speed of 15 miles per hour, up a 5% grade, part of which grade was on a 12 degree curve. The specifications for the formation of the roadway were practically the same as recommended by the American Railway Engineering Association.

Fig. 6. Creosoted Pile Dock at Pedregal for Transfer of Freight and Passengers from Pacific Steamers to Chiriqui Railroad, Showing Passenger Train.

The principal things to be provided for in the construction of a railroad in the tropics are good side ditches and sufficient openings with well constructed culverts and bridges. The rainy season continues for eight months each year, during which time in Chiriqui the rainfall averages about 140 inches or about 3½ times the total precipitation in Illinois for one year.

To provide for the safety of the 57 miles of track, in such floods, it was found necessary to construct 26 steel bridges and 108 culverts.

The majority of the culverts were made of corrugated iron pipe, 24 in. to 72 in. in diameter, with concrete end and wing walls.

All the large pipes under heavy fills were reinforced throughout with one foot thickness of concrete to prevent sagging. The balance of the culverts, 6 ft. by 6 ft. to 10 ft. by 10 ft., were made of reinforced concrete and rubble stone masonry. The American Railway Engineering Association's general specifications for steel railway bridges and coopers E. 30 for minimum loading were adopted.

All of the steel bridges were furnished by the American Bridge Company.

To give some idea of the difficulties in building bridges in such an isolated country, I will say that the bridge material was shipped

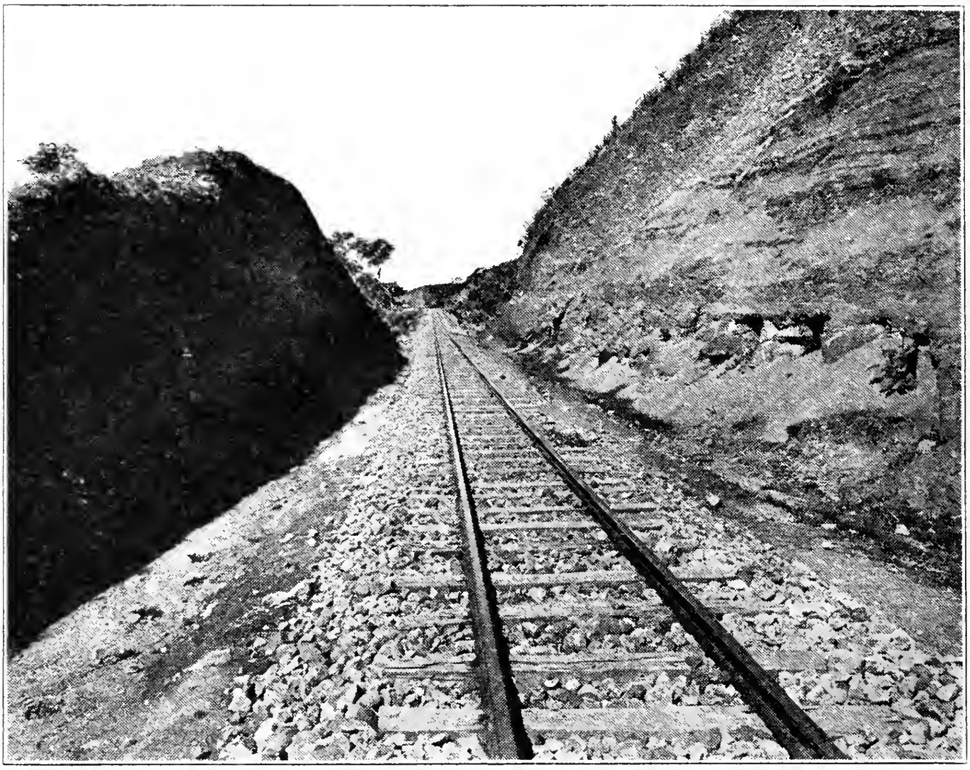

Fig. 7. Typical Rock Ballasted Track with Native Ties.

from New York to Colon, about two thousand miles, and was loaded on Panama Railroad cars and taken across the Isthmus. The larger parts were unloaded on U. S. docks at Pacific entrance to Panama Canal, and reloaded on ocean going barge. The smaller parts were unloaded on docks at Panama, reloaded on small barges and taken out about a mile and transferred to a larger boat which was built for hauling cattle and passengers, with no modern equipment for loading and unloading construction material. The material was then taken up the Pacific coast 325 miles and unloaded at the new dock at Pedregal, to be hauled by work train to bridge sites.

The masonry for the bridges was built in advance of track work, and consequently it was necessary to haul the cement and form lumber in ox carts for five to twenty miles over very bad roads.

The rock for the concrete was crushed by hand at the bridge sites and all concrete was mixed by hand and wheeled into the forms. This method was cheaper than using a concrete mixer.

As soon as the track was laid to a bridge site, the heavy false work timbers for erection, made from native Mangley timber, were delivered by work train, with but one exception, and as soon as erected the steel work was delivered and erected with very little delay. The culvert pipe was all hauled by ox teams and put in place ahead of the grading. All of the concrete work for the culverts was completed after track was laid, to save money in transportation of material.

As soon as the track was laid on the sub-grade for about fifteen miles the ballasting with broken stone was started. As plenty of

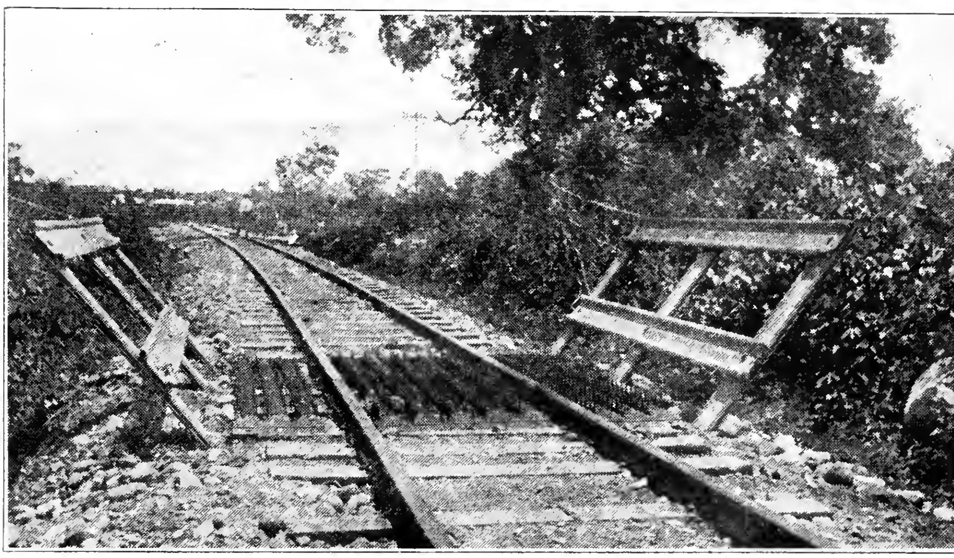

Fig. 8. Steel Surface Cattle Guard with Side Fence Made from Steel Sheet Piling.

stone of good quality was found all along the line between David and Boquete, I suggested to the contractor the use of a portable crusher. He was in favor of a stationary crusher. Finally a young foreman said he believed he could use native labor to break by hand the boulders along each side of the roadbed and rock from the rock cuts and do it cheaper and more satisfactorily than could be done with either a portable or stationary crusher. For experiment he was allowed to break stone for one mile of ballast and it was found he was correct. Consequently all of the broken stone ballast over 33 miles of the road was broken by hand, the big saving being in the fact that it was piled up all along the roadbed in long piles, one foot high by three feet wide, for convenience in estimating, which also saved transportation expenses, as it could be thrown in place with shovels. In the original estimate, creosoted ties 5 in. by 7 in. by 6 ft. were specified. These would have to come from the United

States and about 168,000 would be required. After the contractors had delivered about 40,000 creosoted ties, the Consulting Engineer recommended to the Government that native ties of the best available woods be used. About fifteen varieties of wood were specified, the better quality being Lignum Vitae, Mameycilla, Mora, Moria and Corotu.

The principal reasons for recommending native ties were that the money expended for them would benefit the people in the province and after four or five years they would know from experience the best kind of wood to use in tie renewals for maintenance and

Fig. 9. Line Crossing Rio David Valley—Max. Grades 5%, Max. Curve 12°.

would not be required to wait for shipments from the United States.

While some very good native ties were furnished, yet, as a whole they were not as good as the creosoted ties, and on account of the scarcity of timber and the inexperience of the men furnishing the ties it not only delayed the work but proved to be more expensive than to have shipped creosoted ties from the United States.

It was decided at first to use all 70 pound second-hand rail from the Panama Canal, but after receiving enough for 26 miles of track no more could be had that was good enough for the purpose;

so the balance of the track was laid with new 56 pound rails—both being A. S. C. E. sections.

The right of way fences were built in the same manner as is customary by the natives, by stretching four barbed wires on wild plum posts. Large posts were firmly set in the ground about every 30 feet to stand the pull on the wire, and in between about every 2 to 3 feet small plum posts, 2 in. to 3 in. in diameter, were set about one foot in the ground. These soon take root and grow rapidly, so that in a few years the posts are a line of growing trees,

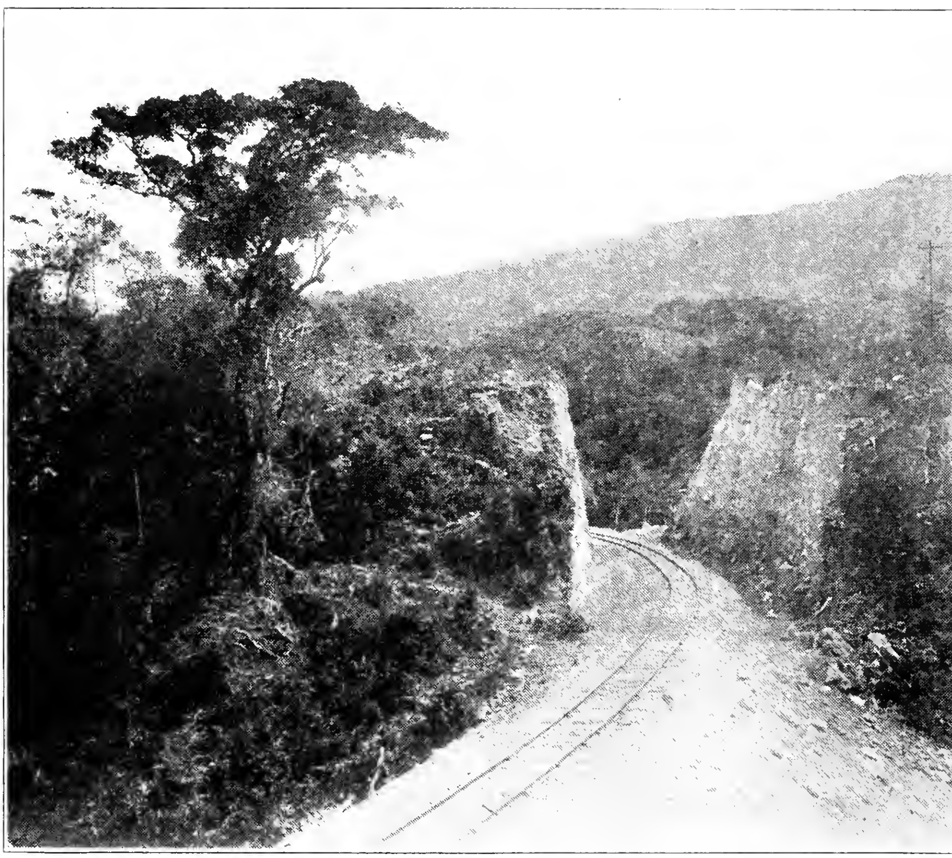

Fig. 10. Line Entering Boquete Valley at Elevation of 3,500 ft. Above Sea Level.

which make a very good fence, with small cost for maintenance. However, on account of the delay in securing the great number of posts required, and the time it takes to build such a fence, I would hereafter recommend for a similar country all indestructible fence posts with five barbed wires.

Most of the cattle guards were steel surface guards with the side fences and posts made by sawing up the sheet piling used at the bridge foundations. This would not be economical in this country, but down there, where we had no more use for the piling and the cost of transportation is high, it was economical. It cost very

little to saw them and drill holes at the shops ready to deliver and erect at the road crossings.

No reverse curves were allowed. The only curves where spirals were used were at places where trains are likely to run at a speed of over 20 miles per hour.

On account of the steep grades the trains will not be required to run at an average speed of over 18 miles per hour; consequently the superelevations of outer rails on curves were made to correspond.

During the construction period, wood was first used in the engines and then coal. The necessary number of oil tanks was being erected so as to be able to change the engines to oil burners soon after the road started operation, as it was proven on the Panama Canal and Panama Railroad that it was cheaper to use oil.

The original form of contract adopted was that known as "cost, plus a percentage, with a bonus for economy."

Soon after the work started I saw the trouble and extra expense it would cause the contractors and the Government to carry out such a contract 325 miles from headquarters.

Under the "cost plus a percentage" form of contract, the contractors were to submit to the Government, for investigation and approval, on the 25th of each month, a complete statement of all expenses incurred on account of the work for the previous month, including pay rolls, canceled accounts, vouchers and all other statements.

This would mean that all the accounts pertaining to the "thousand and one" kinds of expenditure natural to a work of such magnitude and character would have to be prepared in quadruplicate in English and Spanish. This would require a large clerical force for the contractors, and the Government in turn would have to employ accountants to examine this large mass of data each month. This would naturally have caused confusion, misunderstanding and serious delays in effecting payments.

It was then decided to change the contract to a "fixed sum" form of contract, using the same estimate of cost as provided for in the original contract, together with the original specifications. The Government would then have the assurance and satisfaction of knowing that the railway would be completed according to specifications for a guaranteed fixed sum and, if the cost exceeds the contract price, the contractors assume this excess for their account.

The estimated cost or "fixed sum" was $1,628,141, or about $32,563 per mile. Later it was decided to build the Potrerillos Line of seven miles, build a 410 foot span wagon bridge, repair several wagon roads and bridges and construct 50 miles of telephone and telegraph line to aid traffic and operation. This additional work was done at actual cost, with 5% of the cost to go to the contractors for doing the work.

This additional work brought the total cost up to a little over two million dollars.

The contract time for completion was May 1, 1916, but on account of the extra work and heavy rains it was not completed until July 1, 1916.

I will say nothing about the political end of the project, or the criticisms in the press by the opposition party, which develops on all Government work and is generally expected. It is no worse, however, in the Republic of Panama, in that respect, than it is in the United States.

The completed railroad is as well constructed and equipped with rolling stock, shops and station buildings as the average railroad in the United States. The cars are of sufficient capacity to handle the traffic and the railway as a whole will answer all purposes for

Fig. 11. 410 ft. Span Suspension Bridge for Wagon Traffic Over the Rio Chiriqui to Assist in Transportation of Freight to Line of New Railroad.

which it was built as well as would a standard guage railroad. The saving in cost in construction and equipment of a narrow gauge railroad compared with a standard gauge is not as great as many engineers may believe. The principal saving is in the cost of ties, ballast, excavation and bridges, the total saving being approximately only 6 per cent.

As in the case of a great many railroads in the United States, the alignment and grades could have been greatly improved if the additional cost had been allowed. In nine times out of ten the engineers are not to blame for bad alignment and grades, but it is the fault of those who have authority to say what the cost shall be. However, in regard to alignment and grades, of this railway, they

are as good as could be expected for the cost per mile in such a rough country.

It was the consensus of opinion of the Board referred to above that the railroad would not be able to pay operating expenses in twenty years.

The main lines from Pedregal to La Concepcion and to Boquete commenced running trains tri-weekly May 1st. For the month of May the net earnings were about one thousand dollars. Although the cost of maintenance will increase in a few years, it is now believed that it will not only more than pay all expenses in the future but will serve the main purpose for which it was built—"The development and improvement of the country," resulting in a big increase in population of a desirable and progressive class of people.

It is not customary in an engineering paper to go into history and comments, but I have inserted a little in this paper to show the younger members of this Society that very often engineers and contractors have other troubles to deal with besides the ordinary duties of engineering and construction work.

DISCUSSION.

E. T. Howson, M. S. W. E.: There were two or three points that the author brought out that interested me. One was the question of the cheapness of labor and the expense of getting heavy equipment in to the work, as illustrated by his reference to the cost of producing ballast. In this country we have had the opposite condition this past year, with labor very expensive, and even then not procurable at any price. In a comparison such as this, the relative economy of the various methods of handling work depends largely on the supply of labor. As we go into the undeveloped countries, labor is cheap, and the economy resulting from the use of heavy equipment decreases if it does not entirely disappear. In Panama, as we would expect, labor is evidently cheap, and heavy equipment costs more than in this country.

Another thing that the author brought out that is, as he said, contrary to the general impression, is the slight difference in the cost of construction of a standard gauge as compared with a narrow gauge railroad. I think it was about two or three years ago that Mr. Fred Lavis made a similar comparison with reference to the Argentine railways, in an elaborate paper appearing in the proceedings of the American Society of Civil Engineers. As I recall, he checked very closely the figures that the author arrived at.

The difficulty of getting the material in to the line recalls to my mind the estimates now being made relative to the cost of construction of the railways in this country for Federal valuation. Many of our lines were built under similarly severe handicaps, and yet I believe it is the experience of the railways that it is a difficult problem to convince the Federal forces of that expense, as with the absence of records of these early lines it is very difficult, and in many

cases entirely impossible, to prove that expenses have arisen such as those on the railroad which was a pioneer in this territory.

L. K. Sherman, M. W. S. E.: It is work of the kind that Mr. Zinn has described that brings out our admiration for constructive ingenuity in the field. It is there that the engineer and contractor are tested, where perhaps the designing is not out of the ordinary. We have to admire the way the difficulties are met in a peculiar situation.

Mr. Zinn: There is one thing on which I would like to ask the opinion of the engineers. While this Board was discussing the advisability of building this railroad, Captain Rose, who was the electrical engineer, maintained for a long time that it would be better for the Government to first build wagon roads. Captain Wood and I held out that the history of different countries was just the reverse. We advocated building the railroads first so that we could deliver material for building wagon roads at a much smaller cost. The great expense attached to wagon road building down there is to furnish the material. After several days' wrangling we decided to recommend the building of the 3 ft. narrow gauge railroad.

Isn't that the history of this country, that the railroads were built first, and then the wagon roads? That is the question I want to ask. As I remember, the Santa Fe Railroad was built through a new country years and years before they had any suggestion of wagon roads.

W. W. DeBerard, M. W. S. E.: Last summer on a thousand mile automobile trip through Colorado I spent two days at the opening of Wolf Creek Pass Road, which opened up a great mineral and agricultural territory in the Southwestern portion of the state, to say nothing of the Mesa Verde National Park and rich mountain scenery. This Wolf Creek Pass Road was thirty miles in length, and was built at a cost to the state of about $90,000. It has become a competitor of the railroad which goes down into New Mexico and around by the route which Mr. Roper told of recently. The ranch owners can save $26 a car by driving their cattle and sheep over the road to a railroad station on this side of the range. The road to Southern California is shortened by 300 miles and the railroad time to such places as Pagosa Springs is shortened by automobiles about six hours. The railroad has already made a survey paralleling the highway, partially at least, to Pagosa Springs. It is said that it will very materially reduce the cost of the railroad to have a highway already constructed. The engineers constructing the Moffat line had to build a wagon road to get in supplies to the inaccessible Gore Canon.

I would like to ask Mr. Zinn about the proposed construction of wagon roads or motor truck roads in Colombia. I understand there is very much of an agitation for motor truck roads rather than for railroads. There is at the present time, I believe, a project under foot to build 150 or 200 miles—perhaps not as long as that—

from Medellin down to the Magdalena River. At the present time the combined railroad and boat facilities are extremely limited. It is necessary to transship about three times, and in the dry season no freight moves at all.

Mr. Zinn: I never heard of that, and I believe they will find it the same as we found it in Panama, that wagon road work is very expensive in the tropics, and the maintenance is a great deal more than the maintenance of a railroad, on account of the terrific rains.

I remember when I was on the Panama Canal work, we built about thirty miles of wagon road, and that is one thing that made me in favor of railroads first. We built about four miles of wagon road parallel with the Panama Railroad, and built it for about $4,000 a mile. There are other wagon roads running out through the jungle that cost foom $9,000 to $12,000 a mile, where we had to deliver the material with teams or any way we could get the material out there. Along this line of railway that I showed tonight, from David out to Boquetta thirty-two miles, the government spent $300,000 on wagon roads, and yet you will find some of the worst looking road you ever saw, hardly fit to go over at all, although built of fairly good material, the bad condition being due to heavy rains and the steep slopes. Where the natural slope is about five feet in a hundred, or 250 feet in a mile, you can imagine what those torrents mean. So that if the conditions are the same in Colombia as they are in Panama, I think they will find that wagon roads are an expensive proposition.

A cheap way to build wagon roads in those countries is to use a portable crusher and move it ahead and depend on the side hills that you strike for the rock. Even then those roads cost about $9,000 per mile and some of them cost $30,000.

Mr. DeBerard: I think the idea here is to build something very substantial, perhaps spending as much as $20,000 a mile.

S. E. Bates, ASSOC. W. S. E.: In regard to roads and railroads, I believe there was a Santa Fe Trail about two hundred years before the Santa Fe Railroad. However, I don't know that you would call that a road in the modern sense.

There are two questions I would like to ask: First, about this slope of one-quarter to one. About fifteen or twenty years ago an engineer on the Canadian Pacific did about the same thing in Saskatchewan on relocation of the Canadian Pacific Railroad. In other words, cuts originally specified 1½ to 1 were finally made with a vertical slope. The material was stiff clay, I believe. The last time I saw them, in 1909 or 1910, very little material had washed down. Of course, that is an arid climate, with probably ten or twelve inches of rain in a year. I would like to ask what kind of material is found down in Panama in those cuts.

The second inquiry I would like to make is as to the details of the change of that contract from a percentage basis to a lump sum.

Mr. Zinn: Most of those cuts were changed. Originally they

called for a 1 to 1 slope, and where we decided to change to a ¼ to 1, most of it was in that cemented material. About 90% of the material was boulders with a sort of cemented sand in between. I have seen those cuts where there was really an overhang, and we had no trouble with them. In fact, some of them have been there for two years.

My attention was first called to the matter by the natives. They showed me some cuts that had been made for wagon roads that they claimed had been there for twenty-five years, and they were still standing almost vertical. About three-quarters of our cuts were in material that would stand on that slope. The others were made 1 to 1.

Mr. Bates: Was it something like a soft conglomerate?

Mr. Zinn: It was something like that when opened up, but when exposed to the sun it seemed to harden. Some of the material on a ¼ to 1 slope was cemented sand without any boulders at all.

Mr. Bates: What was the cementing material?

Mr. Zinn: I really don't know.

In regard to the contract, that was arrived at in this way: This committee that I was on was furnished with the actual surveys and profiles, and they gave the exact amount of cut and fill. And then they figured so much a yard for concrete and so much for excavation, and the other details. It amounted to one million, six hundred and some odd thousand dollars. When it was changed from a cost plus percentage basis to a fixed sum, we used these same figures and same estimates, which was agreeable to the Government.

Mr. Bates: Did the contractor make any money, or did he lose?

Mr. Zinn: I believe he made some money. But on account of changing the bridges—I had a great many of them lengthened—of course we had a good deal of trouble. I don't care to go into detail, but they finally agreed to lengthen them, and the construction was first class.

Mr. Bates: What would have happened if the contractor had refused to take the job on that basis after bidding the other way?

Mr. Zinn: Then, of course, we would have followed the contract on a cost plus percentage basis. We came to an agreement which was sort of give and take. He had to make certain concessions, and the Government had to make concessions. And it was as a part of that agreement that we got him to do this other work so cheap, on which he claimed he did not make any money. He did this other work on actual cost plus five per cent. Of course we had to check that up in every detail.

Mr. Bates: Five per cent is pretty small on that kind of work, it seems to me,—ten or fifteen per cent is the more usual figure.

Mr. Zinn: Yes, he claimed he should have received ten or twelve per cent.

Mr. Bates: What is the rate of wages for the natives?

Mr. Zinn: That is a pretty hard question to answer. You will get some of them for a dollar a day gold—that is a dollar in our money—and others you have to pay more. There is no fixed salary there. And that was the cause of a great deal of trouble with some of our native labor. They would want to earn about twenty dollars to buy a suit of clothes or something, and as soon as they earned the twenty dollars, they would quit.

C. W. Baldridge, M. W. S. E.: Speaking of the vertical cut, I know of two cases in the United States where it is used. The Chicago and Northwestern have a line near Sioux City which has a number of cuts practically vertical, and the material is largely clay with gravel and sand in it; that stands very well. Another place where there is even a more defined vertical cut and better standing material is at Natchez, Mississippi. At Natchez I noticed a number of cuts that stand just as straight up and down as the side of a house, and after being exposed to the weather a few months that material appears to be plaster, that is, in effect. The color does not change, but it hardens about an inch in thickness. It breaks off just like so much plaster, and after the material underneath is exposed it commences to harden.

Mr. Sherman: I would like to ask Mr. Zinn if there is any local condition that would make that corrugated culvert pipe fail on his road that would not apply in the United States.

Mr. Zinn: There is really no difference in regard to the fills over those culverts than you have in the States. None of those culverts actually failed. They simply sagged three or four inches at the top and looked bad. Of course it was a political job and I knew that we would be criticized if anyone noticed the sags. So in several places where they sagged we had them taken out and replaced with new culvert pipe, and reinforced.

I know that on the Panama Railroad that cost $200,000 a mile, the majority of their culverts are built of this same kind of corrugated steel pipe, with concrete end walls, and while they never used any over three feet in diameter, I never heard any complaint at all of failing or sagging.

I would like to ask if anyone knows the life of a corrugated iron culvert pipe. I have been trying to find out and the longest I can find has been in use about twenty years and it is still good. I know it is a quick way and a rather cheap way of putting in culverts on new work. It is easily hauled in place and easily constructed.

Mr. Bates: Who paid for taking out those culverts and covering with concrete?

Mr. Zinn: The contractor agreed to do that. It did not cost him very much. One place where we had a 72-inch pipe in, we decided that a four-foot pipe would carry all the water, so a four-foot pipe was substituted for the 72-inch, and we left that bottom

part of the 72-inch in and set the other inside of it, and that was put in without any reinforcing and did not sag at all.

Leonard Mauel, ASSOC. W. S. E.: Some of the things that the speaker has mentioned tonight in regard to the understanding, I know to be true in the countries that I worked in. We used the two-thirds slopes in Brazil throughout the entire line. Some of the borrow pits that had been opened for over two years, that had been filled with water all during the rainy season, retained their vertical slope during that time. I did not notice any of the material falling. Some of them were as deep as three meters—about ten feet.

President Grant: I suppose if the material would not stand up in a country where they had a real rainfall it would have to be a flat country, would it not? It would eventually be washed flat if the material would not stand well.

William B. Jackson, M. W. S. E.: I would like to ask what relation the United States Government has in the matter of the bond issues of Panama?

Mr. Zinn: Before they could make the bond issue valid, they had to have the approval of the Secretary of State of the United States. The money was furnished by the National City Bank of New York.

IN MEMORIAM

LAWRENCE GUSTAV HALLBERG

Died December 4, 1915.

Lawrence Gustav Hallberg was born in Wenersnas, Sweden, September 4, 1844. His early education was in the public and private schools preparatory to the Chalmer Polytechnic Institute of Gottenberg, Sweden, where he was graduated in the class of 1866. He spent a good deal of time in European travel and was engaged in architecture under Sir Digby Watts of London.

He came to Chicago in 1871 and engaged in the practice of architecture until his death.

In 1881 he married Florence P. Estey, who survives him, and had four children, Mrs. Margaret Hallberg Rankin, Mrs. Marie Hallberg Hodges, Lawrence G. Hallberg, Jr., and Norman D. Hallberg.

He built many residential buildings, but his chief work was in the line of reinforced concrete factories and warehouses.

He was a Fellow of the American Institute of Architects, a Charter Member of the Chicago Architects Business Association, Member of the Chicago Association of Commerce, the Chicago Real Estate Board, the Western Society of Engineers and a few social organizations.

He enjoyed good health until two weeks before his death, which occurred on December 4th, 1915.

Memoir prepared by F. E. Davidson and Ralph C. Llewellyn, Committee.

LIGHTNER HENDERSON

Died March 17, 1916

Mr. Lightner Henderson died in Chicago, March 17th, 1916, and was buried the following Sunday in Graceland Cemetery.

Mr. Henderson came of a long line of American ancestry. He was born December 2, 1866, on an old family estate at Gap, Pennsylvania, purchased by his forefathers from William Penn. His father, Archibald Lightner Henderson, was an Episcopalian of Scotch-Irish descent, and his mother was a Quaker of English descent. He was reared in the place of his birth, and educated in his native state. He attended the County Public Schools, the State Normal School at Millersville, and graduated from Lehigh University in 1889, receiving the degree of C. E.

Mr. Henderson's first important employment was with Binder and Seifert of Philadelphia, and later for a short time he was employed in Cleveland. He came to Chicago in the summer of 1891, and was employed by Mr. Corydon T. Purdy, with whom he later became associated, under the title of Purdy & Henderson, Civil Engineers and Consulting Engineers in the construction of buildings.

In the work of the company, which covered a wide range and included much important construction, Mr. Henderson shared the responsibility and in many large structures he was solely responsible for the character of the design.

His achievements during these years, from 1893 through two decades, were notable, and mark him as one of the great structural engineers of his day. He was of a very retiring disposition and rather shunned the association of other men. On this account, he was not as widely known, and the quite remarkable character of the man was not as widely recognized as it would have been otherwise, but those with whom he had business relations appreciated him, and depended upon him without questioning. He was also honored by his business associates, who understood his ability and never failed to give heed to his suggestions. They all pay tribute to his unerring judgment.

Mr. Henderson had a very fine analytical mind. Few men have greater power than he had to follow a course of reasoning, to separate the important from the unimportant, and to finally arrive at a correct conclusion of a difficult problem.

The results of his examination and study of any matter, constructive or otherwise, could be depended upon. It might be very complex and it might involve laborious calculations or unusual conditions, yet he never went astray. Along with his analytcal powers of mind, there was also always a practical turn to it, which never was submerged by the complication or the laborious character of a difficulty. He did not arrive at irrational or impracticable conclusions. Simplicity was the distinguishng mark of his designing. It was these two qualities of mind combined that made him so successful in his profession.

There was another side to the man's character, however, which appealed particularly to his associates, his family, and his friends; it was his sterling honesty and sense of justice. In every business transaction, and indeed in every relation and detail of life, he was governed absolutely by a fairness of mind, which came to influence his associates more than any other trait of character could have done.

When Purdy and Henderson's business was incorporated in 1901, he became its first president; this position he continued to hold until about a year before his death. He joined the Western Society of Engineers in September, 1891.

November, 1916

Mr. Henderson was very domestic in his tastes. He was married on March 19, 1902, to Hannah Manson, who with his two daughters, Margaret, 13 years old, and Harriet, 11 years, survive him.

Mr. Henderson passed away in the prime of his life, and this made the loss all the greater both to his family and his friends.

Memoir prepared by Corydon T. Purdy, A. D. Mott and Joachim G. Giaver, Committee.

LOUIS PECK MOREHOUSE, HON. M. W. S. E.

Died March 18, 1916

Louis Peck Morehouse, born in New Haven, Conn., March 30, 1835, died in Los Angeles, California, March 18, 1916.

After graduating from Yale as B. Ph. in 1856, Mr. Morehouse was engaged on the preliminary survey of the New London & Stonington Railroad as rodman. During part of 1856 and 1857 he taught school in Standford, Conn., and in May, 1857, came to Chicago and entered the employ of the Illinois Central Railroad Co., with which he held positions as assistant chief engineer, land commissioner and tax commissioner, covering a period of 48 years of continual service.

Mr. Morehouse retired from the Illinois Central Railroad Co. in 1905, and the account of his railroad career affords an interesting retrospect in railroad development.

At the time that Mr. Morehouse became connected with the Illinois Central that railroad was the longest in the country, being 705 miles in length. Its Chicago passenger station, destroyed by the great fire of 1871, was the largest and finest building of that class in the country. Mr. Morehouse continued in the engineering department of that road for 20 years, or until 1877, being promoted during this time from position of assistant to division engineer to that of assistant chief engineer. In 1877 the engineerng department of the ralroad was abolished in the "interests of economy." The official statement of the reason for this very unusual proceeding being that "the road having been completed for more than 20 years, the employment of engineers was no longer necessary."

After the breaking up of the engineering department, as thus explained, Mr. Morehouse was for a year in the office of the president and of the general auditor. From 1878 to 1887 he was tax agent, in charge of all the tax business of the company, and from 1887 to 1890 he was land commissioner and tax agent. From 1890 to 1898 he was tax commissioner and custodian of deeds, and from 1898 to 1905 custodian of deeds.

From his long railway career Mr. Morehouse could recall

many occurrences which furnished interesting contrasts with later day methods of operation. It is interesting to note that shortly after the opening of the road the management took up the matter of using coal for fuel in place of wood, and Mr. J. C. Clarke, master of transportation, in his report for 1857, stated that he anticipated that his "difficulties in its use would be soon overcome." At this time the speed of passenger trains had, for safety, been reduced to 20 miles an hour, and it was a mooted question whether one or two daily passenger trains should be operated between Chicago and Cairo.

Having made the surveys and prepared the plans and estimates for the proposed harbor improvements under the Lake Front Act of 1869, Mr. Morehouse was frequently called as a witness during the long litigation following. Contrary to the popular belief, the Illinois Central Railroad was not the originator of the scheme "to steal the Chicago harbor," as it is generally put. The plan originated with a syndicate of capitalists, who presented it to a number of members of the legislature, some of whom did not regard it favorably. If, however, the railroad company would take hold of it, they stated that they would give it their support. The Illinois Central was thus brought into the affair and consented to act as the beneficiary. The results are matters of history.

On May 25, 1869, twelve civil engineers, the most eminent then in this section of our country, held a meeting to organize the "Civil Engineers Club of the Northwest," and Mr. Morehouse was chosen as secretary of the Club, with Col. R. B. Mason the first president. Mr. Morehouse in his minutes and public addresses related many interesting incidents of the Club's early history and struggles during the twelve years of its infancy and youth.

At this time, June, 1880, the membership had increased to about 139, and the Club felt that it would be safe to organize into a society. The name was accordingly changed to "The Western Society of Engineers," and Mr. Morehouse continued his valuable services as secretary until his resignation in 1889, when the Society elected him Honorary Member, or as President Octave Chanute said in one of his addresses, "our worthy secretary of eighteen and one-half years resigned to become our greatly esteemed Honorary Member."

At the annual meeting of the Society in 1902 Mr. Morehouse addressed the audience, telling them of the early meeting places of the Club and Society. The first few meetings were held in Col. Mason's office, corner of Lake and Dearborn Streets, and then in August, 1869, "we began," said Mr. Morehouse, "to hold meetings at the Sherman House. The October meeting of 1871 was set for the eleventh, but the great fire which occurred on that night destroyed the Sherman House along with many others in the city of Chicago, and we were without a home. But on the 20th of November we met again. The Sherman House had not risen from

its ashes, materially, but it had risen nominally as the New Sherman House and was located on the West Side, and so we met again, enjoying the hospitality of the Sherman House."

Mr. Morehouse's personal relations with his superior officers and associates in the railroad and Western Society of Engineers were always very pleasant, and he had many warm friendships with eminent men and builders of this city. In October, 1861, he marrient Miss Fredrika Gerhardt, who, with their daughter Clara and two sons, George Gerhardt and Frederick Ballard, survive him.

In everything he undertook Mr. Morehouse was conscientious, painstaking and patient, and as a natural consequence his work was accepted with confidence by his superior officers. That his measure of usefulness was large, is established by his long term of service with one company through different administrations, and always in a position of trust.

As secretary of this Society, he served with the same faithfulness, giving unremitting attention to the many little things, none of which must be forgotten, and which in aggregate at times became a burden. This burden he carried for nearly twenty years—gathering, computing, recording and turning over to his successor the whole history of The Western Society of Engineers from its inception to the fullness of its strength.

The Western Society of Engineers will not forget this, but will ever hold in affectionate esteem the memory of Louis Peck Morehouse.

Memoir prepared by Robert W. Hunt, David Sloan, Hiero B. Herr, Lyman E. Cooley and A. V. Powell, Committee.

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings

Meeting No. 947, October 25, 1916.

A Joint meeting with the Chicago Section of the American Institute of Electrical Engineers was called to order in Fullerton Hall, Art Institute, at 8:10 p. m., with Mr. Taliaferro Milton, Chairman of the Chicago Section, A. I. E. E., in the chair and about 500 members and guests present.

Announcement was made by Mr. Glenn Muffly of a proposed flight by Mr. Victor Carlstrom by aeroplane from Chicago to New York, starting on Monday, the 30th instant. Mr. Muffly announced that the machine to be used, as well as a number of others, would be on exhibition at the aviation field on Saturday, the 28th instant.

Mr. Junkersfeld introduced Dr. Charles P. Steinmetz, who delivered a very interesting and instructive address on "The Effect of the European War on American Industries."

The meeting adjourned at 9 p. m.

Meeting No. 948, November 6, 1916.

The meeting was called to order in the Society Rooms at about 8 p. m., by President Grant, with about fifty members and guests present.

The Secretary announced that the following had been elected to membership in the Society under the Grades specified:

Eugene Gellona, Sanitago, Chile............................Junior Member
Eugene E. Altman, Chicago.................................Junior Member
George J. Trinkaus, Chicago................................Junior Member

and that the following had made application for admission on transfer:

Jacob J. Jacobs, Chicago.
Richard M. Quirk, Chicago.
Francis M. Howell, Evanston.
John Edgar Freeman, Chicago.
Edwin Hope Verrall, Evanston.
Roy Eugene Berg, Chicago.
Samuel E. Sosna, Chicago; Transfer from Student.
Grosvenor W. Stickney, Chicago.
Frank L. Phipps, Chihcago.

The Secretary also announced the death of the following members of the Society, both of whom had been members for more than twenty years:

Virgil G. Bogue, October 15, 1916.
C. W. Hotchkiss, October 28, 1916.

The President introduced Mr. A. S. Zinn, M. W. S. E., who presented a paper on "The Construction of a Narrow Gauge Railroad in the Republic of Panama."

Discussion followed by Messrs. E. T. Howson, L. K. Sherman, C. W.

Baldridge, W. W. DeBerard, Stanley E. Bates, L. Mauel, N. M. Stineman and William B. Jackson.

The paper was illustrated by lantern slides. The meeting adjourned at 9:30 p. m.

Meeting No. 949, November 13, 1916.

The meeting was called to order at 7:50 p. m. by Chairman Lacher of the Bridge and Structural Section, with about sixty members and guests present. The Secretary announced the death of Mr. E. T. Hendee, M. W. S. E., who died on November 12, 1916.

The Chairman introduced Professor Humphrey of the Forest Products Laboratory at Madison, Wisconsin, who read his paper on "Timber Decay and Its Growing Importance to the Engineer and Architect." The paper was illustrated by lantern slides and specimens.

Discussion followed by Messrs. T. L. D. Hadwen, Peter Leichenko, W. E. Williams, J. W. Lowell, F. E. Davidson, J. P. Cowing, Finch and H. L. Potter.

The meeting adjourned at 11 p. m.

Meeting No. 950, November 20, 1916.

The meeting was called to order at 8 p. m. by Chairman DeBerard of the Hydraulic, Sanitary and Municipal Section, with about 140 members and guests present.

Prof. F. H. Newell extended to the members of the Society an invitation to attend the dedication on December 6th and 7th of the Ceramic Engineering Building recently completed at the University of Illinois.

The Chairman introduced Dr. Clifford Richardson, consulting engineer of New York city, who read a paper on the "Importance of the Relation of Solid Surfaces and Liquid Films in Some Types of Engineering Construction." The paper was illustrated by lantern slides and motion pictures.

The paper was followed by discussion by Mr. Edward N. Eaton, Prof. Mickey and Messrs. W. W. DeBerard, P. E. Green, A. J. Schafmayer, Lester Kirschbraun, C. C. Dowdell and Stanley E. Bates.

The meeting adjourned at 10:40 p. m.

Meeting No. 951, November 27, 1916.

A joint meeting with the Chicago Section of the American Institute of Electrical Engineers was called to order at 7:40 p. m. in the rooms of the Western Society of Engineers, with Mr. Taliaferro Milton in the chair, and about 150 members and guests present.

The program for the evening consisted of two papers, the first being by Mr. B. G. Lamme on "Temperature Distributions in Electrical Machinery," and the second by Mr. F. D. Newbury on "Rational Temperature Guarantees for Large Alternating Current Generators."

The Secretary read a written discussion by Prof. Grey of Cornell University, Mr. M. M. Fowler read a written discussion by Mr. Foster, and Mr. C. A. Keller read a written discussion by Mr. C. J. Fechheimer. Mr. V. M. Montzinger also read a written discussion. Oral discussion followed by Messrs. P. Junkersfeld, P. M. Lincoln, N. J. Conrad, C. A. Keller, M. M. Fowler, W. E. Williams and Prof. Bauer. The discussion was followed by an extended closure by the authors.

The meeting adjourned at 10:45 p. m.

E. N. LAYFIELD, Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE TO BE FOUND IN THE LIBRARY OF THE SOCIETY.

HANDBOOK FOR HIGHWAY ENGINEERS. By Wilson G. Harger, First Assistant Engineer, New York State Department of Highways, and Edmund A. Bonney, Supervising Engineer, New York State Department of Highways. McGraw-Hill Book Co., New York, 1916. 600 pages. 4 inches by 7 inches. Price, $3.00 net.

This edition follows the same arrangement as the well-known first edition which appeared in 1912. Considerable progress has, however, been made in the practice of road design and construction since that time, and the revised edition is intended to bring the book to date. About 100 pages have been added, much of the old material revised and a much better index has been included. Special items mentioned by the authors as having been brought to date are top courses and data on tests, designs, costs, maintenance and specifications.

For those not familiar with the old edition, it should be said that it purported to "collect, in a compact and convenient form, information ordinarily required in the field and office practice of road design and construction," the book being designed to meet the requirements of "both experienced and inexperienced road men."

The success of the first edition is sufficient evidence that this intention was fulfilled.

The book has many tables and illustrations.

The contents are as follows:

PART I.

Chapter 1.—Grades and Alignment.
Chapter 2.—Sections.
Chapter 3.—Drainage: Culverts, Small-Span Bridges, and Under Drainage.
Chapter 4.—Foundations for Broken Stone Roads.
Chapter 5.—Top Courses and Their Maintenance.
Chapter 6.—Minor Points: Guard-Rails, Retaining Walls and Curbs.
Chapter 7.—Materials.

PART II.

Chapter 8.—The Survey.
Chapter 9.—Office Practice: Mapping the Preliminary Survey, the Design and Miscellaneous Points.
Chapter 10.—Cost Data and Estimates.
Chapter 11.—Notes on Construction.
Chapter 12.—Specifications: Materials and Methods of Construction.
Appendix A.—Traffic Rules and Regulations of the States of Ohio and New York.

Journal of the

Western Society of Engineers

Vol. XXI. DECEMBER, 1916 No. 10

THINGS WE DO NOT KNOW ABOUT STRUCTURAL ENGINEERING

W. M. Wilson, M. W. S. E.

Presented October 9, 1916.

CRITERION OF THE QUALITY OF A DESIGN

The fact that a structure has not failed is not proof that it was properly designed. Structures are generally designed with a factor of safety of about 2, based upon the elastic limit. The fact that the structure has not failed is evidence only that all members have a factor of safety of at least 1, and there is no evidence to show that some members do not have an excess of material.

If a design is good because the structure does not fail, the design of the ancients should be copied, whereas they are known to be so wasteful of material as to be prohibitive.

For a design to be good it must be well balanced. Although a structure *must* be safe, it also *should* be economical. In stating that a structure must be well balanced, I do not mean that the ratio of strength to stress necessarily shall be the same for all members. Many other factors besides strength must be considered. If the failure of a small part will destroy a whole structure, the factor of safety in the small part should be greater than the factor of safety for larger or less critical parts. This is illustrated by the second Quebec bridge disaster. Because of saving in shop costs it is sometimes cheaper to build a member that is too large than it is to build a member that will just carry the load to which it is subjected. Because of the small amount of material involved, it is often cheaper to use an excess of material than it is to make an exact analysis of the stresses. An increase in the live load may cause a much greater increase in the total stress in one member than in other members of the same structure, therefore, if there is a possibility of an increase in the live load, such a member should have a greater margin of safety in the original design than other members of the structure. Some members upon which a structure as a whole depends, such as the end post of a truss, are subject to accidental forces, and, although

*Assistant Professor of Structural Engineering, University of Illinois.

neither the probability of the load occurring nor the magnitude of the stress produced, can be expressed mathematically, these accidental forces should be considered in designing the member. In some structures metal is added above what is required to carry the stress, because the structure is especially liable to corrosion. In such a case all members are not increased by the same relative amount. In some structures rigidity and "feel" of the structure must be considered. This is especially true of railroad bridges, in which it is not only necessary that the bridge figure safe but also it must ride as it is safe. Bearing in mind the factors that have just been enumerated, a design, to be good, must be well balanced. Although it is good engineering to make some members of a structure larger than stress alone requires when there is a definite object to be attained, it is not good engineering to make a member unnecessarily large because of ignorance of its true function.

Good engineering is the best insurance against failure; and wasted material is a tribute to ignorance.

DESIGNING NOT SOLELY A MATHEMATICAL PROCESS

It is not true, as the beginner is likely to believe, that the design of a structure is made up only of exact mathematical processes, and that the results are therefore infallible. In general with known forces acting upon a structure the stresses are determined mathematically, and with the total stress in a member known, the area of the section is determined by dividing the stress by the allowable unit stress for the material, after which it remains to select a section having the required area. Thus the structure is designed and apparently only mathematical processes are used. The thing that has been entirely overlooked, however, is the fact that for every mathematical equation used, assumptions have been made in deriving the equation and these assumptions have been entirely neglected in applying the equation. The accuracy of the results depends not only upon the accuracy of the mathematical processes, but also upon the accuracy of the assumptions upon which the mathematical processes are based.

ASSUMPTIONS IN THE DESIGN OF A STEEL RAILROAD BRIDGE

To illustrate the importance of assumptions, consider the design of a steel railroad bridge. The design may be divided into four parts, as follows: determination of the loads to be carried; calculations of the stresses; design of the members; and design of the connections.

The load upon a bridge consists of the dead load, live load, impact, wind load, and lateral forces due to a moving train. The dead load can be determined satisfactorily from the design of other bridges. The live load, although fixed arbitrarily, can be accepted as quite satisfactory except that future live loads are problematic. Impact is usually computed from the live load by empirical formula based more or less upon tests. Wind forces and lateral forces due

to a moving train cannot be determined satisfactorily. The lateral forces to be used in a design are usually given in specifications. Specifications, however, differ, and some engineers feel that all the specifications are wrong in some particulars as regards lateral forces. Clearly the lateral force to be used in the design is not the same for bridges in all locations.

The stresses in a bridge, as usually computed, due to known forces, are based upon the following assumptions:

1. All external forces are applied at the panel points.
2. The weights of the members are applied at their ends.
3. The axial gravity lines of all members connected at a panel point are concurrent.
4. The connections are frictionless hinges.

Assumption 1 is usually fulfilled. Assumption 2 is fulfilled for all practical purposes for vertical members; the fact that it is not fulfilled for horizontal and inclined members does not produce appreciable error except in the case of long members. In the case of long members a correction can be made for the bending stress due to the weight of the member. Assumption 3 can be and should be fulfilled, except as it may be desirable to have a little eccentricity in a joint to offset the error in assumption 2. Assumption 4 is not fulfilled, and because it is not fulfilled secondary stresses are produced which may be 50 per cent. or more of the primary stresses.

In designing a member it is customary to assume that the stress is uniformly distributed over the entire section. Likewise in designing a riveted connection it is assumed that the stress is uniformly distributed among all of the rivets. These two assumptions are discussed later.

ASSUMPTIONS WHICH ARE NOT CORRECT

Omitting the assumptions relative to the loads, it is apparent that the assumptions which enter the design of a bridge which demand special attention on the part of the designer refer to the following: secondary stresses; distribution of stress in a member; and distribution of stress in a connection.

Secondary Stresses: One of the fundamental assumptions in stress analysis is that connections are frictionless hinges. If a truss having frictionless hinges is deflected, the members meeting at a joint are free to rotate relative to each other and no bending stresses are produced in the members. If, however, the connections are rigid, when a truss is deflected the members are not free to rotate relative to each other, and bending stresses, known as secondary stresses, are produced. These secondary stresses can be determined mathematically. While all are willing to admit that, theoretically, secondary stresses exist, many, apparently because of the elaborateness of the calculations necessary for their determination, look upon them as something invented by the mathematician for the further torture of the soul of the engineer. The strain-gage, however, has come to the support of the mathematician and secondary stresses are known to be a reality.

Secondary stresses equal to 50 per cent. of the primary stresses are common. To just what extent such secondary stresses increase the danger of failure, however, is not clear. Upon first thought it would seem that introducing a secondary stress equal to 50 per cent. of the primary stress would increase the danger of failure as much as if the primary stress were increased 50 per cent. This, however, is not the case. A secondary stress, being a bending stress, is not uniform over the section, and if the maximum values of the combined primary and secondary unit stresses exceeds the proportional limit of the material, Hooke's law no longer applies, and there will be but little increase in the combined stress beyond the proportional limit, Just what value of combined primary and secondary stress can be used as a working stress has not been agreed upon by engineers.

Although secondary stresses can be computed, the calculations are so long that they are not at present made except in the case of the more important structures. For ordinary structures secondary stresses do not appear in the calculations and are not mentioned in the specifications. The view is held by many engineers that secondary stresses need not be considered, since with an allowable unit stress of 16,000 lbs. per sq. in. a secondary stress equal to 50 per cent. of the primary stress produces a total stress considerably below the yield point of the material. If secondary stresses were equal in all members of a truss and in all types of trusses this position could be defended, since the method would result in a structure for which all members would have the same factor of safety. But secondary stresses do not bear the same relation to the primary stresses in all members of a truss, and the secondary stresses are not the same in all types of trusses. The result is that designs are not properly balanced. Furthermore, we are unable to judge intelligently of the relative merits of different types of trusses.

The calculation of secondary stresses is a long and tedious process, but, like a long journey, it shortens with repetition. In the early days of bridge design, moment tables were unknown. Moreover, to the student first introduced to the problem of primary stresses due to moving loads, the determination of the stresses in a six-panel truss due to a Cooper's loading is almost an overwhelming job, even with a moment table, whereas, to the experienced designer equipped with modern tables it is a small part of a forenoon's work. If we once recognize the necessity of determining secondary stresses, may we not hope for a similar development in the methods by which they are determined? The design of short and medium length spans has been standardized, and if the secondary stresses are computed in a few of each of the common types of trusses, may we not hope to establish empirical laws by means of which the secondary stresses in other trusses may be determined in a comparatively short time? Thus it will be possible to design all members with approximately the same factor of safety after secondary stresses have been included.

The resulting more perfectly balanced design would be a suffi-

cient reason for making an extended systematic study of secondary stresses in standard trusses. There are, however, other results to be obtained from such a study which are even more important. A more intimate knowledge of secondary stresses would result in the abandonment of types of trusses having high secondary stresses and the substitution for them of trusses having low secondary stresses. An illustration of this is to be found in the attempts to use the K type of truss of the Quebec bridge for shorter spans. Moreover, being confronted with high secondary stresses, the engineer would exercise his ingenuity to devise details which would reduce the secondary stresses. This is illustrated by the recent use of pin connections between the floor beams and trusses to reduce the secondary stresses in the vertical posts of trusses.

Distribution of Stresses in a Member: The area of the section required for a member subjected to a known stress is obtained by dividing the total stress by the allowable unit stress for the material. This is virtually equivalent to assuming that the stress is uniformly distributed over the area of a section of the member. Tests show

Fig 1.

that if an angle is riveted to a gusset plate by means of rivets in one leg only, the full strength of the angle cannot be developed. Members of trusses are much larger than the single angles tested and some portions of the section are a considerable distance from the central point in the connection. Engineers recognize the necessity of attaching the member to the gusset plate over as large a portion of the section as possible. If portions of the main member, such as the outstanding legs of angles, are not in contact with the gusset plate these portions are connected to the gusset plate by means of lug angles. In considering the value of lug angles, it is well to bear in mind that where there are several paths for a stress the portions of the total stress which travel over the different paths depend upon the relative stiffness of the paths. To illustrate the truth of this statement consider the apparatus represented by Fig. 1. The blocks A and B are connected by two wires, one is a small tightly drawn wire and the other is a large slack wire. By inspection the stress is transmitted through the rigid path provided by the small tightly drawn wire and but little if any of the stress is trans-

mitted through the less rigid path provided by the large slack wire. Consider again the case of an angle riveted to a gusset plate. The connection of one leg to the gusset plate by means of a rivet holding the two pieces in immediate contact is very rigid. A lug angle attached to the gusset plate and to the outstanding leg of the main angle, comparatively speaking, is not rigid. The result is that a strain which ruptures the leg of the angle riveted directly to the gusset plate produces but little stress in the lug angle. This statement is supported by tests. Reasoning by analogy, if the different parts of a connection are not equally rigid the stiffer parts may be overstressed, if not actually ruptured, before the more flexible parts of the connection receive an appreciable stress. It is true that as the stress in the most rigid part passes its proportional limit a part of its load is automatically transferred to other parts of the connection, but in the case of the angle connected to the gusset plate one part of the connection is so much more rigid than the other that the two parts act in succession instead of in unison. The same action is even more likely to occur in the connections for large truss members. Let me repeat, the portion of the stress which follows one path depends not at all upon the strength of the path, but depends entirely upon its rigidity, and the stress in a member is not uniformly distributed over a section at the end unless the different parts of the connection are properly proportioned, one to another, relative to their rigidity.

It is the writer's opinion that for ordinary working loads the stress at the end of a member is not uniformly distributed over the section, and that the maximum unit stress is materially greater than the total stress divided by the area of the section. Furthermore, it is the opinion of the writer that ultimate failure of many members connected as they are in bridges, will occur at a stress materially below the ultimate unit strength of the material multiplied by the area of the section of the member. Since the advent of the strain gage the first statement can be either verified or disproved by means of field tests of bridges under normal working conditions without a prohibitive expense. The second statement can be checked by tests to destruction.

The important thing to be revealed by such tests is the efficiency of the different types of sections. This is illustrated by the recent tests made by the Bureau of Standards at Pittsburgh as reported in Engineering News, July 13, 1913. For some of the columns tested failure was due to a part of the section failing independently of the other parts of the section. That is, the full section of the column was not developed. If a member having one section can develop a stress of only 80% of the product, area times unit strength of material, whereas if the member had a different type of section it could, because of the better type of connection possible, develop 90% of the product, area times unit strength of material, then other things being equal the latter type of member should be used. At present we have but little, if any, reliable data relative to the

efficiency of connections for different types of members. We have many opinions, but few facts.

Distribution of Stresses in Connection:—The discussion of the distribution of stresses in a member is equally pertinent to the distribution of stresses in a connection. If the connection is made up of a number of parts each of which is to take a certain prescribed portion of the total stress, each part must have just sufficient rigidity to enable it to take its portion of the total stress. This condition it is practically impossible to obtain.

In a riveted connection the stress is not uniformly distributed among the rivets. The rivets are distributed over a considerable distance and the intensity of the stress in the gusset plate at its outer edge is zero, whereas the intensity of the stress in the member at the same point is a maximum. The intensity of the stress in the main member at its end is zero, whereas the intensity of the stress in the gusset plate at the same point is a maximum. At some intermediate point the intensity of the stresses in the gusset plate and in the main member are equal. Designate this point as the working point. If the main member is in tension, the portion of the member between the working point and the edge of the gusset plate will elongate more under stress than the corresponding part of the gusset plate, and therefore the rivets at the edge of the gusset plate will be strained more than the rivets at the working point. Likewise the portion of the main member between its end and the working point will be stressed less than the corresponding portion of the gusset plate, and therefore the rivets at the end of the main member will be strained more than the rivets at the working point. That is, where we have assumed the stress to be uniformly distributed among the rivets we know that it is not so distributed. It follows, therefore, that the maximum stress per rivet exceeds the quotient, total stress divided by the number of rivets. A comparison of the strain in a riveted joint for ordinary working stresses with the differences in the strains in the gusset plate and the main member, shows that the maximum stress per rivet may be very much greater than the average stress per rivet.

Since a riveted joint, at usual working loads, resists a stress by virtue of the friction between the pieces connected, and since a riveted joint takes a permanent set at loads much below the usual working loads, overload in a rivet subjected to a reversal of stress may cause the rivet to work loose and must be considered as a serious matter. This fact, together with the fact that stresses on rivets are not uniformly distributed, as assumed, but that the maximum may be much greater than the average, indicates that the number of rivets in the connections should be increased, especially for members subjected to a reversal of stress.

The uneven distribution of the stresses can only be reduced by reducing the lap of the main member on the gusset plate. This suggests the desirability of arranging the plates so as to put the rivets in double shear, thus reducing the number required, or, as has been

suggested, of using a comparatively small number of large turned bolts instead of a large number of rivets.

The thickness required for gusset plates is another question that has no satisfactory answer. Some designers claim that a truss can be assembled with only 20% for details, other designers use 50%. In general the details for a railway bridge truss are about 33% of the main members. As gusset plates comprise a large part of the details, the percentage of details depends largely upon the thickness of the plates. The thickness of the plates can not be computed except that the strength of the rivets in bearing should develop the strength of the rivets in shear. Usually the plates are thicker than is necessary to meet this requirement. The outstanding fact is that the weight of a truss can be materially altered by changing the thickness of the gusset plates, and we have no positive evidence determining the proper thickness. We have opinions, of course, but the man who assembles trusses on 25% details is positive that any one using more than 25% is wasting material, whereas the man who uses 50% details is positive that any less than that endangers the structure.

In general, in judging of the merits of a connection, it is well to bear in mind that the main member is the major part and the connection is the minor part, and that it is not good logic to jeopardize the major part to save a little on the minor part. Furthermore, if the life of a bridge is determined by the time it will wear as a machine, it will be the connections that will wear instead of the main members. For this reason also the connections should be stronger than the members.

The whole question of the strength of connections is a field ripe for experimental investigation.

The illustrations that have been used have been taken from bridges, but the designer of buildings must meet similar conditions. Moreover, the examples cited illustrate only a few of the many uncertain quantities which enter the design of a structure.

ADVANTAGES TO BE GAINED FROM A MORE EXACT KNOWLEDGE OF THE BEHAVIOR OF STRUCTURES.

The object in having a more exact knowledge of the behavior of structures is not either to use more material or to use less material, but rather to use the material so that it will do the most good. The structure must be safe, but it should also be economical. The advantages to be gained are economy and safety.

Greater economy in design can be obtained from an increase in knowledge in two ways. If the stress in a member is determined with a high degree of accuracy, what is usually known as a factor of safety is in reality a factor of safety, whereas if the stress is not known, what is termed a factor of safety is largely a factor of ignorance, and the member is made unnecessarily large because of the uncertainty in regard to the stress. If the stress in a member is determined with a high degree of accuracy those types of structures and types of details will be selected for which the secondary stresses

are a minimum, and either the safety of the structure will be increased or the cost of the structure will be decreased.

The most important advantage of an increased knowledge relative to the behavior of a structure is the increase in the safety of the design. Shakespeare says that fear springs from ignorance. To the engineer the unknown is the source of danger.

With very few exceptions, failures have been due, not to error in the calculations, but to error in the assumptions upon which the calculations are based. It is the failure of the material to have the properties with which it is credited, or the failure of the structure to resist a stress in the manner assumed, that causes all failures. Design is not solely a mathematical process. Every equation used is based upon assumptions. These assumptions, the foundation upon which our structure of stress analysis is built, need constant inspection.

Structural engineering has made wonderful progress both in design and manufacture. But it is only by keeping before us the importance of the factors that are neglected that progress is to continue. To the man with an inclination for research work, whether engaged in practicing engineering or in university work, structural engineering is a wonderfully attractive field.

DISCUSSION.

James N. Hatch, M. W. S. E.: The paper by Professor Wilson is very interesting and valuable, and brings out a number of very important points in structural engineering that are often overlooked, or, if not overlooked, are looked upon as being an unwarranted refinement in ordinary structural design.

I quite agree with Professor Wilson that many designs could be improved by considering the various possible secondary stresses, and, no doubt, the time spent in this complicated analysis would be more than justified in many important structures.

I believe that it would be an excellent thing if every designer of important structures were conversant with all the matters mentioned in Professor Wilson's paper, and were able to use them readily. But, looking at the matter from a practical standpoint, it is not clear to me just how or when this branch of the subject should be taught to the young engineer. To me, the most important thing in all design is the ability to make the proper assumptions to start with, for the whole design depends very largely on assumptions. If the assumptions are incorrect, no amount of refinement in the design will correct them. If a young engineer could be taught engineering by a combination of theory and practice so that he could see the practical use of each step that is taken as the theory advances, he would then be able to make the proper use of the various considerations as to the possible action of any member under all possible conditions. But, if too much of this is taught to a student before he has had an opportunity to put any of it into

practice, it is likely to befog the whole situation so that he will be inclined to figure and worry almost indefinitely over very simple problems and will find that his wealth of engineering knowledge is a hindrance rather than a help in getting a start in engineering work.

Suppose, for instance, a young engineer is started to work on the design of a sixteen story building. He would be told, to begin with, to figure the total dead loads as carried by the columns, and, in addition to this, beginning at the top floor, to figure the live loads as 85% on the 16th floor, 75% on the 15th floor, 70% on the 14th floor, 65% on the 13th floor, 60% on the 12th floor, 55% on the 11th floor and 50% on the floors below. He would also be told that the main girders in the building should be figured for only a certain percentage of the load that the beams connecting to them were designed for and the foundations and footings would be determined in accordance with some other assumptions. These assumptions are largely empirical, and vary according to the notion of the person who decides upon them. After starting out with the above assumptions, any fine-haired theory in figuring the design of the members would seem almost useless, because a slight change in the assumptions might change the stresses, in any particular member, very materially.

Or to take another example, suppose the young engineer were designing a steel mill building with a travelling crane carried on the outside columns. Some assumptions would have to be made to begin with. The question would arise as to whether he should design every column in the building strong enough to carry the maximum possible load that the crane would transfer to that column in addition to the roof loads and wind load, or would it be safe to assume that all of these conditions will never conspire. In other words, is it safe to use some percentage of the combined loads, instead of the entire load, and, if so, what should that percentage be? Furthermore, in figuring the foundations of columns, the question arises as to what percentage of the total load should be considered as acting in the foundation. Also, with the wind blowing against the side walls of this building, there would be a tendency to tip the building over, causing an increase in the load on the columns on the leeward side of the building and a decrease in the loads on the windward side of the building. The question is whether this really has any appreciable effect on a building as flexible as an ordinary steel mill building.

Examples might be cited indefinitely showing that all of the problems of a structural engineer are based on assumptions and very often a small change in the assumption, which would seem to be insignificant, will make a very material change in the stress of some particular member.

Almost the first formula that a structural engineer learns is the ordinary beam formula: $M = \frac{SI}{c}$. Of course, we all know that

this is not true for steel beams, because it would only be true if the beam were rigid. And the same might be said of all of the ordinary formulas used in steel work. They are all based on a rigid structure, instead of a flexible structure, so that in actual practice, the stresses that would be found in the steel members are not at all what they appear to be from our figures.

In bringing out the above, I do not wish to be understood to belittle the value of the most careful research in every detail of analysis, but it is a question in my mind whether it would not hinder rather than help the engineering student to encumber his mind with too much of this refined knowledge before he has an opportunity to work gradually along the beaten paths of established practice.

Albert Reichmann, M. W. S. E.: I think sometimes we are inclined to look at a paper like this in a wrong way. I look upon our designing of structures as still in its infancy, and that it is not the student or the young man from college who learns these things. I look upon the designing of structures as being done more through institutions and established practice. We have a great many large engineering offices in this country, for instance the offices of railway companies, and the offices of contracting companies, and offices of civil engineers that make a specialty of designing large structures. Every time that we bring up some good point which improves the character of the design these improvements are embodied in future designs.

I remember not very many years ago, when I was connected with the St. Paul road, we had a lot of very simple pin-connected trusses 35 feet long. I am sure they won't be built again. The young man comes to the work and he finds a different practice. He is likely to start in with the practice established by his predecessors, and he may learn something from somebody, and he may add that knowledge to his profession, and the profession will go along with just a little bit better practice. And therefore I think that a paper of this character is very desirable and helpful to the profession. It is only by bringing out these small points, as the author has brought them out in a good many instances, that we are learning.

He showed the failure of several compression members. I was sorry to see that he did not have a few pictures showing some of the compression failures of columns that have recently been built where there was not quite so much detailed material, and where the column failed nearly as that one. I witnessed some column tests made at the government arsenal at Pittsburgh of a large span where the columns were built somewhat of an I-shaped section. There was, comparatively speaking, very little detail to that, and the behavior of the column was excellent. It performed pretty close to the elastic line, I imagine.

The author referred to the percentage of details used on spans. Now, that is a thing that is very important. I agree with him, that we should see that the details are up to standard. Now, it

does not necessarily follow that you must have 50 per cent. details. Sometimes you can put a little additional material into main members, and eliminate some details. In that way you may get a better structure than you would if you had a 50 per cent. detail. For my part I believe in designing structures so as to eliminate details as far as you can by concentrating your material for the main members.

Another thing: We must consider the structure as acting as a unit. I have often brought out the point, and I think that this point has been embodied somewhat recently in our specifications for railway bridges, and that is the question of providing adequate lateral bracing for our structures.

The author showed where a column failed through its not being properly designed; that is, it failed in the intermediate points rather than as a whole. I believe that a great many of the bridges would fail the same way if they were tested to destruction, that is to say, that we would find that the top chords, the compression chords, would be more liable to act as component parts than act as one whole, that there is not enough lateral bracing there to make the chords act as a unit.

In the case of through-plate girder bridges we run up against a point nowadays that is rather hard on the engineer, in the clearances that our state commissions are establishing. I think some of them call for seventeen feet in the clear, or something like that, so we get pretty long spans and we naturally cut down the gussets that support the topchord.

It seems to me that we ought to develop some column formula to figure the top chord of that through-plate girder as a column from end to end instead of just applying the same gross area to the top chord that we have on the bottom chord. I do not think the conditions are parallel at all. I do not believe, for instance, that the compression members stand up nearly as well in proportion as the tension members do. I think there are a great many other things of that kind in which improvements could be made.

Chairman Lacher: There is one question I would like to ask Mr. Reichmann, and that is as to just what he means by concentrating the material in the section. I understand that, of course, in the selection of sections it is possible to select a section which may not be as economical as to the net amount of material, but which may be much more economical in the detail of the end connections. Is that what you mean?

Mr. Reichmann: No. Now, for instance, I sometimes see people who will build a member of two channels where they might have built an I-shaped section with solid work in between. Theoretically that member won't stand up as well as the other, but if you put it in a testing machine you will find out you will get much better results. You take a large column and build it of I–shaped sections and instead of having elastic members there you have a solid web.

H. J. Burt, M. W. S. E.: It was my expectation that Professor Wilson's paper would catalogue the numerous things we did not know about structural engineering. I have been a little disappointed in that respect, as he has limited himself to a comparatively few items. I have been pleased, however, that he has discussed there problems in a way which indicates that their solution is not wholly unknown to him, although they may be unknown to most of us.

When you come to think of it, there is hardly a computation that we make in designing that does not involve some assumption. Even in the steel skeleton building, which apparently is the simplest thing that an engineer can have to design, we must start with some assumptions. The dead load we can usually figure with some certainty if we take enough care to determine what materials are to be used for the various parts of the structure. For the live load, we accept some one's judgment, perhaps the requirement of the building ordinance, or we attempt to determine the loads that are likely to be imposed upon the building in the use for which it is being designed. We find that buildings very rapidly change in their occupancy, so that the load that we adopt at the time of the design may be very far away from the capacity that is desired for the building in later years. Yet we must make some assumption, and usually for the sake of economy that assumption is made as low as the conditions will permit.

Having disposed of the subject of live load, the next consideration is the wind load. It is surprising how wind loads vary in different parts of the country. In a locality where there is no legal requirement the wind load may be assumed to be zero, and buildings are so designed in a great many cases. Here in Chicago our knowledge of the situation is a little more advanced, and because of the suggestion contained in our local laws, we find that the wind load amounts to 20 pounds per square foot. In New York they have even higher winds, producing a pressure of 30 pounds per square foot. But knowing the amount of the wind pressure does not solve the problem by any means. Those of you who gave some attention to the studies of Professor Wilson and Professor Smith, as they were presented to the Society last year, on the subject of wind stresses on building frame work, realize that the question has not yet been fully solved, or at least that it is not in workable use for ordinary designers. They presented a mass of figures and diagrams which demonstrated that current practice is not correct, but did not teach us quite how to do it correctly.

A building column seems to be one of the easiest elements to design. All you have to do is to figure out the floor area, apply the computed dead load and the assumed live load, make the reductions in the successive stories which are authorized by the building ordinances, add weights of column partitions and any special items of dead or live load. Thus we compute the loads. Then, from a table of columns we select the sections corresponding to the loads and column length. But there are some things to consider

before finally selecting the sections. The column tables are expressed in terms of length of column and assume concentric loading. What is the proper length to use for a column? Is it the story height from center of girders? Is it the net distance between girder connections? Should it be two stories? Or should it be only one-half of a story height? There is ground for argument in favor of any one of these suggestions. Does it matter whether the load comes into the column from two sides, or from four, or from one, or from three? Does it matter whether the floor construction is of a rigid character, as we have in the case of a reinforced concrete slab floor, or whether it is somewhat loosely constructed as in the case of mill construction or ordinary wood joint construction? These things certainly have some effect, but how much?

And the question as to whether there are one, two, three or four girders or beams connecting to the column leads up to the consideration of eccentric loads. We are required by law to make allowance for eccentricity, but how much, is a qeustion. And still more of a question of how much allowance is actually made. The formulas with which I am most familiar in that connection assume that the stress due to eccentricity of a given load is eliminated at the next panel point of the column; that is to say, if you have an eccentric load at the tenth floor, the unequal stresses resulting therefrom gradually equalize, and at the ninth floor the stress in the column has become uniformly distributed over the section. That may be a proper assumption. It has the merit of being easy to use.

If the above assumption is not correct, what is the effect if the eccentric loads are applied successively down the entire length of the column, that is, if there is an eccentric load at each floor instead of an eccentric load at one floor? Is there any cumulative effect? I think there may be, although the ordinary method of figuring does not so conssider it.

In connection with the eccentric stresses in columns, there is the question as to how much benefit we get in case the column is held in position at the floor level by the floor framing, although that floor framing may not be rigid enough to be effective in fixing the direction of the column.

Considering next the bottom of the column we have a situation where a member which has a stress of 12,000 or 14,000 pounds per square inch must be enlarged so that it will have a bearing of 1,000 pounds, or less, per square inch. This is accomplished usually by means of a cast iron pedestal. How do you analyze the stresses in a cast iron pedestal? I believe they defy analysis. Of course, we have means of figuring them. We take a cross section of the casting and compute its resisting moment based on a certain allowable maximum compression. This is undoubtedly a fair guide in determining the section of a casting to use. Then there are certain elements of the casting that apparently are subject to direct compression. Those elements can be analyzed on that basis, if you choose. There may be some overhanging edges of the bottom plate

of the casting that can be computed by bending. The result is that we get cast iron pedestals which give the service for which they are designed. But I would not venture to assert that the real stresses at any point in a casting so designed even approximate what we compute them to be. I imagine our pedestals are too heavy, but we cannot reduce them until we have some basis for computing that is better founded than anything we have now.

The question of the structure as a whole has been brought up by Mr. Reichmann, and that is something to which we give very little consideration, whereas if we understood the joint action of the materials thoroughly we might effect some very considerable economies. It is a common practice in Chicago to use concrete as a fire proofing material, casting it about the steel column to furnish that protection. The ordinances of Chicago recognize the value of this concrete in stiffening the column and allow an increased stress or load to be placed upon the column on that account. That allowance, however, does not seem to be a consistent thing because it allows 2,000 pounds per square inch additional load on the column without reference whatsoever to the relative proportion of the column area to the concrete area. Under the law we may apply the same rule to a column that has ten square inches of metal and 400 square inches of concrete that we apply to a column that has 150 square inches of metal and 300 square inches of concrete. Now, manifestly that is not the proper relation between these things, although unquestionably there is some benefit to be secured from the use of the concrete around the column.

Very often we have a column which is wholly or partially built into a wall. In the basement wall of a building it may be entirely enclosed in a heavy concrete wall. Are we not entitled to figure this as a short column? In the upper part of the building one-half of the column may be enclosed in a brick masonry wall. We surely get some benefit from this combination, but how to reduce it to figures is quite another matter.

Proportioning of the column is another point on which we need further information. Doubtless the column tests that have been made will disclose some guidance in that regard. Take the case of the H section, built of a web plate, flange angles and cover plates; how much thickness of web plate should we have to carry 40 square inches of flange? Should we have 1⅝ plates, or 2¾ plates? What thickness of angles should we have for connecting the flange to the web? Should it be governed by the maximum thickness of angle that can be fabricated without reaming, or should there be some real relation between the thickness of this angle and the thickness and area of the flanges of the column? What proportion of thickness of flanges should we have for a given thickness of web to avoid buckling of the web? What thickness of the outstanding flange should we have in proportion to the width of the flange, and to its length? Perhaps some of these questions have been fairly well answered by the tests, but if so I am not familliar with them.

Steel lintels in masonry walls present a problem. They should not be designed for bending only, for the materials which they support are relatively rigid. A slight deflection in the lintel would cause cracks in the masonry or cause it to arch over the opening. In a brick wall a lintel will get some load as the brickwork is built upon it. Presently the brickwork arches over and the lintel gets no further load. And yet under these conditions we do not always take into account whether there is anything to resist the thrust of the brick arch.

When it comes to the questions of the effects of temperature and moisture of the elements of a structure, the subject gets almost too complicated even for suggesting questions, so I leave it there.

Chairman Lacher: This discussion that we have had tonight reminds me of the story of the young man who was studying law in a lawyer's office. After he had been there about two months the boss asked him how he liked law. He says, "Oh, I don't like it at all. I am sorry I learned it." Well, I think that the average bright young fellow that has learned how to figure a plate girder and determine the stresses in a statically determinate frame truss thinks that he has just about learned it. And it takes a discussion of this kind to show him how much he doesn't know and how much the rest of the profession doesn't know.

We are always going further in intricate mathematics in an attempt to investigate the stresses of the more complicated, or what the books call the higher structures, and yet these investigations are always such a length ahead of the tests that make such analysis practicable that the progress is much slower than we would like to see it. Even with the columns we are still quite a distance behind. And when we come to concrete structures we really are still very much at sea.

Ernest McCullough, M. W. S. E.: Concrete designers have not enjoyed the use of such books as Carnegie and Cambria pocket-books for steel designers, so have been forced to rely upon the owner's pocket book. Unfortunately this sort of designing has ruled in too much of the reinforced concrete designing in this country, precisely as the same reliance on the owner's pocket book formerly led to dishonest and incompetent designing of steel highway bridges. Secondary stresses were once entirely disregarded but now they have assumed such importance that we can hardly blame the over educated young engineer who quit the business and took up something safer, and became a floor walker in a dry goods store.

Reinforced concrete designers have gone farther than steel designers in the adoption of the principle of continuity in designing. They were forced to it because of the monolithic character of the work. To say that the bending coefficient for a beam was $\frac{1}{8}$ did not make it so when the beam was continuous, for the maximum moment is over the support. It is not $\frac{1}{8}$ at that point so the chance to save steel and concrete was grasped. The principle of continuity

involves the idea of positively rigid supports, so today the foundations for concrete buildings are given more careful consideration than in the past.

The flat slab, or girderless slab, is now having a trial before the studious men of the profession. Several thousand buildings are standing with such floors in them, resting on enlarged column heads. We have several sorts of four-way floors, several two-way floors, a combination of two and four-way and some with steel in circles. The greater number seem to be doing good service and no complaints are heard. They were all designed after tests and the rules were consquently empirical. Lately an analysis was made which impressed our leading engineers and the Joint Committee has prepared a method for design which the owners of the flat slab patents say will ruin them and drive the flat slab out of existence. Here is a case where the slabs seem to be designed in contradiction of well known mechanical principles yet they stand. The laws of flexure seem to be obeyed with reinforced concrete beams and if they are apparently not obeyed by the girderless slab it is because of exceptional items in the construction.

In regard to using the concrete placed around a steel column for fireproofing. This is of service before a fire comes but should not be used. Professor Talbot a few years ago showed that when a steel column enclosed a concrete core the strength of the steel column was increased by the concrete carrying a small load. In Chicago when a steel column is encased in concrete and encloses a core of concrete the usual straight line column formula can be used with a maximum stress of 16,000 lbs. instead of 14,000 lbs. and with $18{,}000 = 70\frac{l}{r}$. This should be used with care.

Mathematically with a beam having a uniform moment of inertia throughout its length and resting on more than two supports the sum of an end coefficient and the coefficient at the middle of the span is ⅛. A number of designers have therefore used a coefficient of 1/12 in the middle of the span and 1/24 over the supports, not recognizing the fact that the maximum moment is over the support. It is true that if the beam is designed for 1/12 *wl* in the middle the actual bending moment developed over the support will be 1/24 *wl*. provided the moment of inertia is constant. To alter the amount of steel to take care of this small moment changes the moment of inertia and increases the stress. We are now getting educated. Chicago requires the sum of the center and one end coefficient to be 1/6.

Less than one hundred years ago the knowledge of how to compute stresses in frames was acquired. Thirty years later the beam theory was put on a substantial basis. That we have done as well as we have done is remarkable. Just as we figured that there was little more to be known, if indeed it was not all known now, the mathematicians come along with their secondary stress matters to

plague us. Before they are all settled the present generation will be dead.

The mathematics of the question have been pretty well settled. It is now a question of the sort of materials we are given to work with and the methods to be used in fabricating the materials and combining the sections to act as wholes. This is a big help to the worker and the man with actual experience is going to be ahead of the man with the school knowledge. The man in the school, however, with his testing machines and well equipped laboratory, is crowding the worker on the outside pretty hard. Mr. Wilson said he was going to tell us what we did not know about structural engineering. He has treated us very nicely indeed and no doubt every man here could, if he had the courage, tell Mr. Wilson about quite a number of items he overlooked.

F. E. Davidson, M. W. S. E.: I was much interested in Mr. McCullough's remarks that engineers who are now designing reinforced concrete and flat slab work concede that there is such a thing as flexure. It has always been a question in my mind as to whether or not engineers have the right to assume, in the design of flat slab concrete floors, the theory of the continuous beam, when the supports were not fixed. I remember discussing this question with Mr. Winslow of the Building Department of Chicago some time ago, when the astonishing statement was made by him that the foundations for one of the columns in an important downtown building had settled 2½ inches. As the entire building is of monolithic concrete, with flat slabs, I cannot conceive of any engineer being able to calculate the theoretical stresses in the floor slabs or in the column head adjacent to the column that settled. In fact, I don't know how the building stands up, but it is there.

In my own practice I have never used the flat slab design or continuous beam unless their supports were unyielding. The continuous beam is predicated upon unyielding supports, or at least that was the theory when I was at school.

When I visited the University of Illinois last spring I remember discussing this question with Professor Talbot and I believe with Professor Newell and Professor Wilson, and suggesting to them that one of the things that the engineering profession today was in need of was some data regarding stresses which would be set up in a continuous beam having yielding supports. I also pointed out that the profession needed information on the effect of intense heat upon flat slab concrete floors when fully loaded. I do not know of any accurate data showing the effect of intense fire upon a thin flat slab of loaded concrete. There have been numerous intense fires in buildings having joists and girder construction, but what is the effect of intense heat upon a thin flat slab stressed as theoretically the flat slab is stressed under maximum load?

I am advised that the National Fireproofing Company some time ago built a test flat slab 20 ft. square, designed in accordance with the requirements of the Chicago Building Code. After cur-

ing, the slab was loaded and a fire built under it. The slab deflected permanently about 3½ inches, I am advised. Will similar results follow an intense fire in the flat slab buildings now in existence?

Another thing I don't know is how to prevent check cracking in concrete. I cannot think of any more important work which the Experimental Station or the State University, or even the Cement Producers' Association, could take up and perform than to find out, and then to tell the engineering profession and those using concrete, how to prevent check cracking.

I agree with Mr. McCullough that so far as the pure mathematics of design are concerned that we know how to figure structures. It is the materials themselves that we do not yet know, nor how they will act under all conditions. These are some of the things we don't know about structural engineering today.

H. P. Gillette: I should like to offer a few suggestions upon one line of data of which we engineers are considerably in ignorance, namely, the coefficient of sliding friction. The Austin Dam in Texas, which failed about sixteen years ago, failed, in my judgment, because the engineers did not know what the sliding friction coefficient was in the materials that underlaid the dam. The Quebec bridge disaster the other day, I think, may be attributed to a similar cause. The coefficient of sliding friction assumed by the bridge designers, according to the chief draftsman of the Quebec Bridge Company, was 10 per cent for friction between the longitudinal pins and bearings in the rocker bearings or universal joint, and this 10 per cent was under a unit pressure of over 5,000 pounds per square inch. There are, so far as I know, no test data whatever upon sliding friction at that load, particularly on pins or other journals. The highest that I can find are about 1,000 pounds to the square inch and Professor Thurston's tests showed that the coefficient of friction increases at about the cubic root of the unit pressure. If that law holds beyond the limits of his tests, then the coefficient of sliding friction was 30 per cent on these pins in the Quebec Bridge, and not 10 per cent. And if it was 30 per cent, then we have a complete reason for the failure without attributing it to the weakness of the castings.

Now, it seems to me that one of the things that engineers should insist upon is that data cannot be applied beyond the limits of the tests with safety, and when they are so applied the factors of safety should be correspondingly large. Normal factors of safety are not sufficient for the purpose, when applied to unit pressures beyond the limits under which tests to determine coefficients of friction were made.

Chairman Lacher: There are many other cases where the coefficient of friction raises a question. For instance, the bearings of the re-enforced concrete trestle slab as used on railroads on its abutments. It has been realized that the coefficient of friction of concrete on concrete has been too high to obtain sufficiently small temperature stresses, and metal bearings have been introduced, but

still there remains the question as to how much the coefficient is being reduced by the introduction of these bearings. There seems to be no data available.

F. G. Vent, M. W. S. E.: I believe there are few engineers that have heard Professor Wilson's paper on this subject of secondary stresses but who will appreciate the subject. I also believe there are many compensations that nature provides that tend to reduce the secondary stresses as calculated. I investigated a span on the Rock Island System to see whether we could carry it over for a few years with a heavier loading. It was a span built by the Lassig Bridge Company about 1890. The average stresses in the members were about 21,000 pounds, in the compression members. The hip joint was a very bad joint. The members did not intersect under centers of gravity. Some of them were nearly four inches off, and the rivets were very badly proportioned. They were not put where they should be in regard to the center of gravity of the member. After taking all the rivets into consideration and making a test of the secondary stresses in the joint by proportioning the rotating moment of the joint to the various members it ran up to 42,000 pounds per square inch. Of course, that bridge was taken out. But it shows that the bridge was in actual service when the stresses were probably well beyond the elastic limit. Some compensations had crept in and seemed to save the structure.

In a pin bridge with the pressures that are allowed on the pins of 22,000 pounds per square inch, it seems, although the data are lacking on the amount of friction to figure on under heavy pressures, that pins would turn, but we have to exercise great care in taking different elements into consideration. For instance, we might throw the secondary stress on some I-bars, but you could equally say that half of that stress would go in the form of torsion through the pin. In using the strain gauge you have to be very careful to keep from confusing any stress which might be accounted as an impact, taking stresses on different parts of the members to arrive at any definite conclusions. I believe after you get through that there are a lot of compensations that come in that tend to save the structure the same as in the riveted span just mentioned.

I had a case in which I figured a 250-foot span for a man, and he wanted to get the design worked up to submit in the form of a bid. And he asked me what per cent of detail I thought there ought to be on it. I said, "30 per cent." We made the cover plates 30 inches wide, and used details like those of some other bridges of different spans, and when he figured up the percentage of these details they were about 45. He thought that there was something wrong. We found that we could trim down the percentage of detail on floor beams and other details, and got that down to about 38 per cent. It seemed as though he could not get it any further by trimming details in floor beams and other members, and finally I suggested cutting the cover plates to 27 inches, and found that cut out 8 per cent of detail, so that we got it down to 30 per cent.

When we got through, the bridge looked better and the compression members looked better.

I bring out this point to show that sometimes a small detail like a cover plate makes a great difference in percentage of details, in thicknesses of lacings, cover plates, batten plates, etc.

My experience has been that in a satisfactorily designed bridge the percentage of detail will be about 30. A pin span may have slightly less than a riveted span.

I will cite a good illustration in the 720-foot double track span for the Metropolis Bridge which will probably be the longest simple span built. In working up the preliminary design of this span I found that the dead load stresses were a large item, being in many members as large as the live load stresses, and hence gave espcial attention to the details so as not to add unnecessarily to the dead load and at the same time to obtain thoroughly satisfactory construction.

This involved calculating, carefully, the weight of details upon each member of the bridge and reducing the weight so found to percentage of weight of the main portion of the various members. After doing this and averaging up the per cent of detail on the entire span, I found the average to be 29.7 per cent. I might mention that this was a pin span with some of the minor joints partly riveted and was based on high carbon steel in the compression members of the trusses, as against silicon steel as finally adopted.

O. H. Basquin, M. W. S. E.: I think that this paper will do good in calling attention to fundamental assumptions. The assumptions that the author emphasizes are important ones to structural engineering. I think it would be appropriate to extend the discussion to some things that underlie structural engineering, but are generally classed as belonging to other subjects such as testing materials and metallurgy.

The structural engineer assumes that his material is initially free from stress, that it is homogeneous, and that the various parts of his structure are so accurately made that they will fit together in erection without the introduction of erection stresses. All of these assumptions are far from the facts that characterize many structures.

The structural engineer assumes that his steel acts in an elastic manner until the applied stresses become rather large, but tests generally show a small set at small loads. Concrete and masonry show marked deformation with time when under load; such effects are certainly small in steel, but it is not evident that they are absent. It has been advocated that initial stresses disappear with time in steel; if this is the case will not secondary stresses that are due to dead load also slowly diminish?

Steel becomes harder and stronger under the influence of cold work. If secondary stresses produce yielding in some member near a joint, is this member injured or improved? I suspect that the answer will depend much upon circumstances surrounding the member so distorted, particularly whether it is subject to a reversal of bending.

A few years ago we had much investigation of strength under combined stresses, in an attempt to find the real criterion of strength. This matter has not been properly completed, and the information that has been gained has not been put in proper form for the easy use of the structural designer.

It is about time for the structural engineer to be very much more than one who is skilled in the mathematics of structures. He should, in my estimation, have a deep understanding of strength of materials, be very familiar with the phenomena that are shown in tests, and have a considerable knowledge of the structure of steel as understood by the metallurgist.

Professor Wilson: I wish to express my appreciation to the members of the Society for their reception of the idea which I tried to embody in the paper, that we must halt our mathematical investigations until we construct the foundation upon which they rest. We must check the assumptions upon which our mathematical analyses are based.

I have been guilty of making as many elaborate analyses of stresses as any one, but in continuing my work I came to the place where I said, "I cannot go ahead with this investigation until I establish the assumptions on which I am working." And that is the way I think we must all feel about the matter. These fine mathematical calculations are entirely out of place if they are based upon assumptions which may be from 50 to 100% in error. This means that our work of the immediate future is experimental work, either in the laboratory or in the field—probably the latter.

I am very glad that Mr. Reichmann emphasized so strongly the thing that has been learned from the tests of columns made by the Bureau of Standards. I pointed out that a number of members failed because they were not properly designed. Mr. Reichmann stated that he had recently seen columns tested which showed that they were properly designed. The valuable thing which we get from tests is this, members of a certain type will develop the strength which they should develop, and members of a certain other type will not develop the strength which they should develop and therefore should not be used. That fact, once established, is available for the use of all engineers.

Mr. Burt in speaking of the work done by Professor Smith and myself on the analysis of wind stresses in office building frames, said: "They presented a mass of figures and diagrams which demonstrated that current practice is not correct, but did not teach us quite how to do it correctly." The following quotation is taken from page 47, Bulletin No. 80, Engineering Experiment Station, University of Illinois:

"Methods II and III of Section II are so inaccurate that they should never be used; I and IV are quite accurate in some cases, but they may give results which are seriously in error.

"While the slope-deflection method is long, it could be used in the actual design of a building; but it has its greatest value as a

standard by means of which the accuracy of the approximate methods may be determined."

Four approximate methods are in use for determining the wind stresses in the frames of office buildings. These methods when applied to a frame of a building give radically different results. In the absence of any accurate method it was impossible to determine which of the approximate methods is the most accurate. As a result of the investigation made jointly by Mr. Maney and the writer, presented in the Bulletin referred to above, it was found that for a symmetrical three-span bent having columns of equal sections two methods, designated as Method I and Method IV, are accurate enough for purposes of design. (This would be gratifying to Mr. Burt inasmuch as Method IV is the one which he uses.)

This investigation is referred to at some length because it is a fine illustration of the practical value that may come from an investigation which at first glance is so intricate that no layman would attempt to follow it. If an analysis is complicated or if a problem defies analysis, empirical rules are used; but laboratory tests and elaborate mathematical analyses are required to establish accurate empirical rules.

I am gratified to note that the practicing engineer is not going to throw back upon the universities all of the work of improving structural engineering practice. It is as Mr. Reichmann has said, advancement can only be made by the practicing engineer's eliminating, one at a time, the faults in our present practice. The undergraduate does not have time to consider the advancement of engineering practice. He has four years in college, practically three years are devoted to science and languages, and one year is devoted to engineering. We can not hope to give in one year more than the generally accepted principles of engineering. The students' contribution to the practice of engineering must come after graduation. It is for you, employers of engineering graduates, to use these students to advance the science of engineering.

A COMPARISON OF THE ACTIVATED SLUDGE AND THE IMHOFF TANK-TRICKLING FILTER PROCESSES OF SEWAGE TREATMENT

By Harrison P. Eddy.*

Presented October 16, 1916.

The activated sludge process, during the past two years, has taken a prominent place among methods of treating sewage. There have been many investigations to determine its capabilities and the engineering profession is indebted to several investigators who have generously placed the data thus acquired at the disposal of whomever may be interested.

The primary function of this process is the oxidation of organic matter through the agency of bacteria living in the presence of an ample supply of oxygen. As this is the primary function of the trickling filter also, it is important to know which is the more advantageous process. This can only be determined by a comparison of the respective costs of the two processes and an analysis of their individual advantages and disadvantages. In making such studies the local conditions in each case must be given their merited weight. In the comparison discussed in this paper the problem has been applied to the conditions existing at Fitchburg, Mass., where an Imhoff tank-trickling filter plant has been in successful operation since October, 1914.

Fitchburg has a population somewhat exceeding 40,000 and is situated on the north branch of Nashua River, which has a drainage area of about 65 square miles above the lower boundary of the city. The Nashua River flows into the Merrimac from which the City of Lawrence is supplied with water after filtration. The drainage area of the Merrimac at this point is 4,663 sq. mi.

The purpose in treating the sewage of Fitchburg was to prevent the pollution of the Nashua River to an extent which would make it objectionable or likely to become a nuisance. It was not necessary to secure an effluent having a high degree of bacterial purity.

The following discussion of construction and operation costs is based on studies of two treatment plants, one for the Imhoff tank-trickling filter process, and the other for the activated sludge process, both plants being designed to fulfill the same conditions. The trickling filter plant has been based on the design and cost of the plant at Fitchburg, Mass., with such modifications as are necessary to reduce the costs to units suitable for comparison. The activated sludge plant has been designed to meet the same conditions, and where possible, the same unit costs of construction have been employed. The design has been based upon experience gained from

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several experimental installations operated by the author during the past year and from data procured from Milwaukee and other reports.

Basis of Design.—Both plants have been designed to care for the sewage from a population of 55,000 persons. The average quantity of sewage is assumed to be 100 gal. per capita per day, equivalent to 5,500,000 gal. per 24 hours, and the detention period in Imhoff and humus tanks has been based upon a day-time flow of 125% of this average.

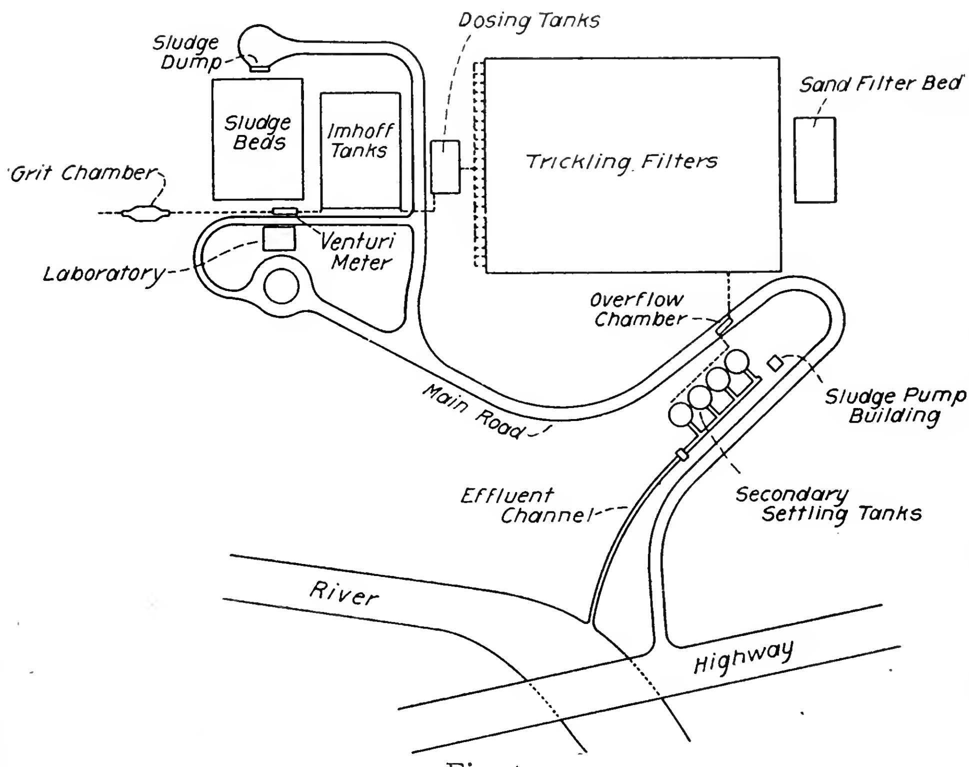


Fig. 1.

Plan of Typical Trickling Filter Plant for Sewage Treatment.

IMHOFF TANK-TRICKLING FILTER PLANT.

The description of the Imhoff tank-trickling filter plant as built at Fitchburg, has been made rather complete, as it may be of interest and the data of value to some of the members of your Society. The only material modification made in the Fitchburg design to aid in this comparison was to increase the size of the trickling filters and dosing tanks to serve a population of 55,000 instead of 40,000 persons. The remainder of the plant was built to serve a population of 55,000.

Grit Chamber.—A grit chamber is provided for the deposition of gravel and sand carried along in the combined sewers during and after storms, the design being such that a velocity of

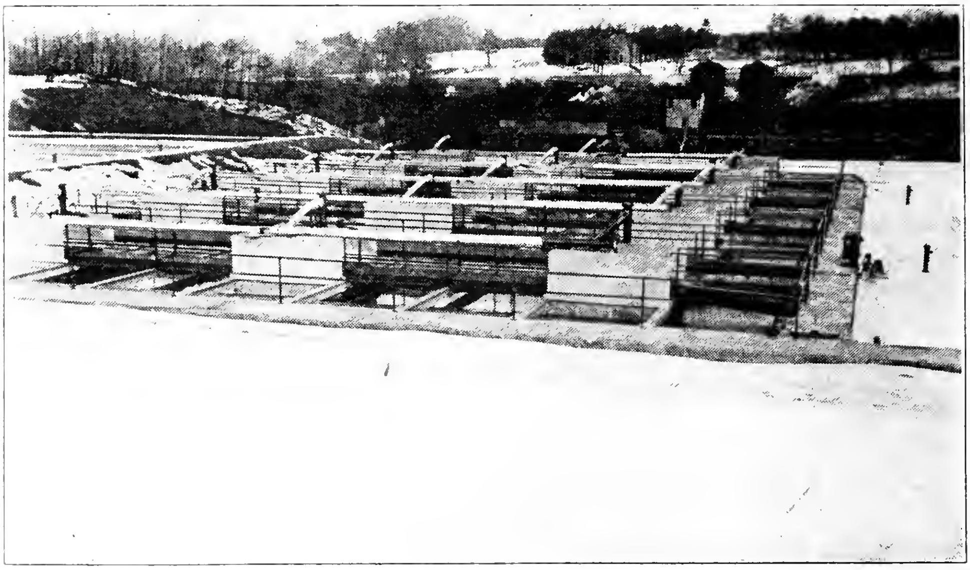


Fig. 2.
Imhoff Tanks, Fitchburg.

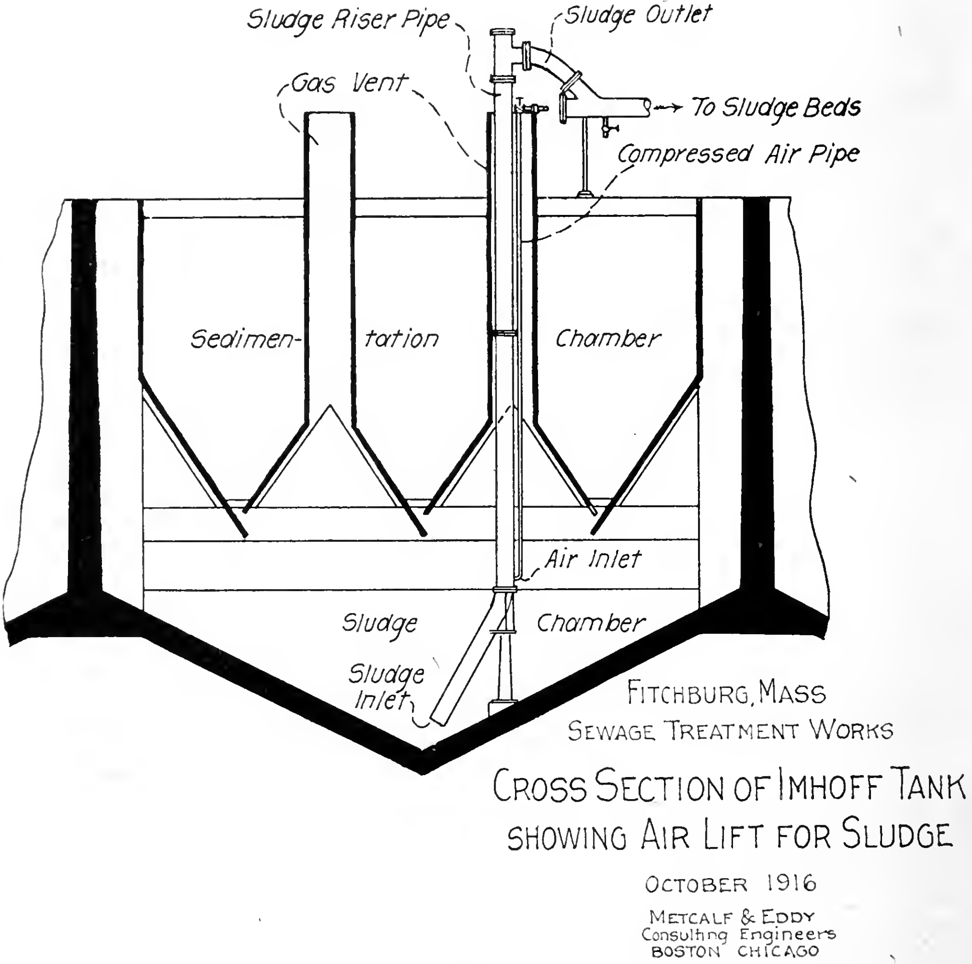


Fig. 3.

about 1 ft. per second can be maintained, so as to prevent the deposition of much putrescible matter. The purpose of removing the heavy inorganic material at this point is to prevent its retention in the Imhoff tanks from which it would have to be removed at considerable expense if, as seems probable, it would not flow with the sludge to the suction pipe.

Screens.—At the lower end of the grit chamber a coarse rack of inclined bars about 1½ in. apart is provided to remove coarse trash which might cause trouble in the pipe lines and Imhoff tanks.

Venturi Meter.—A venturi meter with suitable indicating and recording apparatus, is provided to furnish accurate continuous records of the flow of sewage, as an aid in the intelligent operation of the plant. This meter is set in a concrete vault below the surface of the ground, where the up-stream and down-stream piezometer

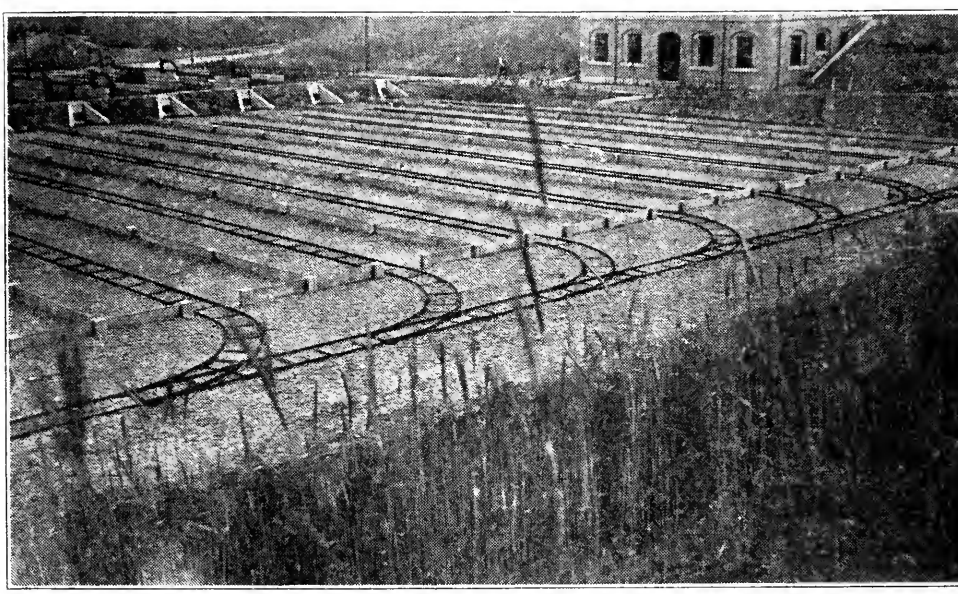


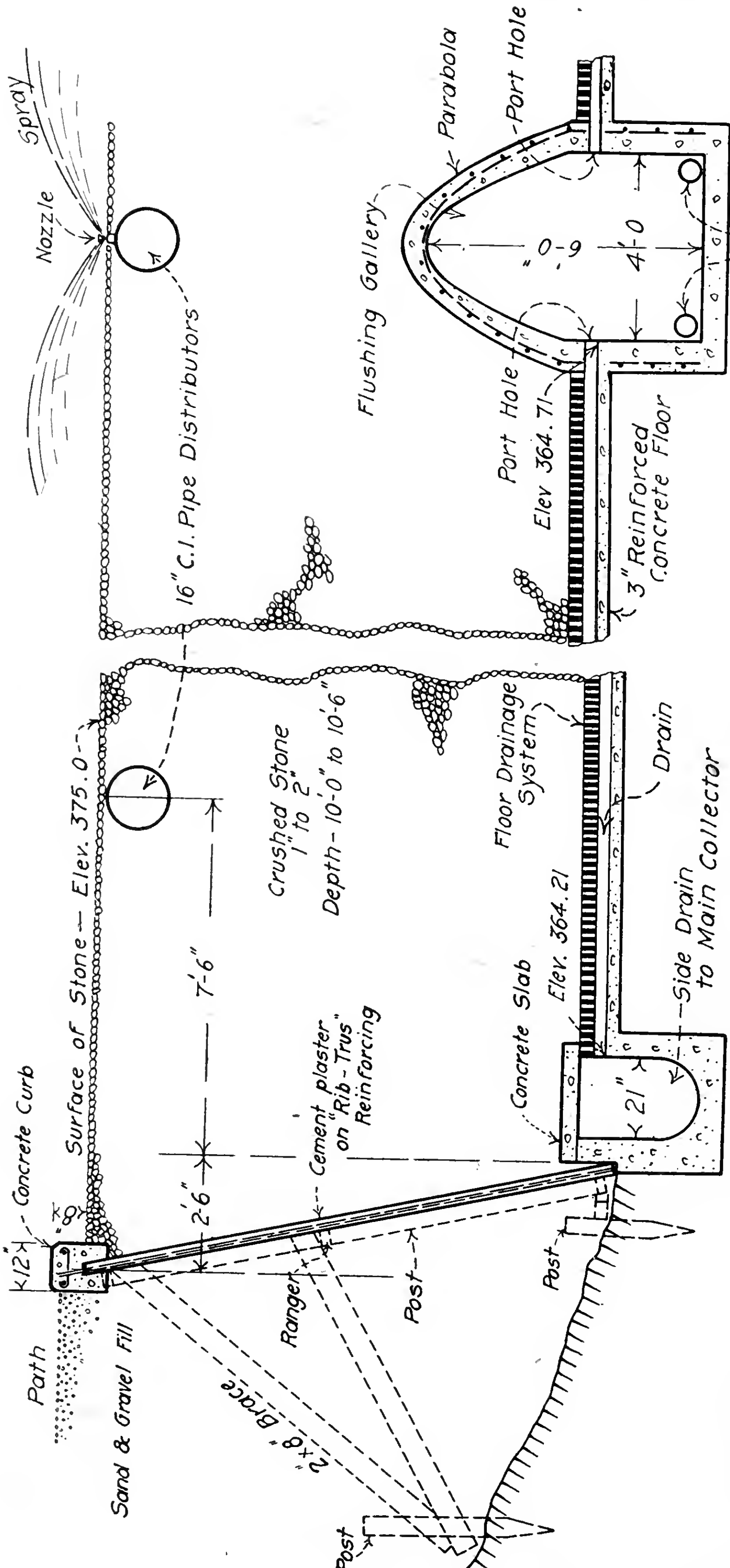
Fig. 4.

Sludge Drying Beds

rings are accessible at all times for inspection and cleaning. Pipe connections extend to float wells in the laboratory building where the recording apparatus is located.

Imhoff Tanks.—There are five rectangular Imhoff tanks, each 30 ft. wide by 90 ft. long inside. The tanks are designed to have a sedimentation period of 3 hours. The quantity of sludge provided for is 1.26 cu. ft. per capita, which is equivalent to about 0.007 cu. ft. per capita per day for a period of six months. In addition, considerable space is allowed for the accumulation of scum and for the moderately clear water between the sludge and scum. The total working* capacity of the Imhoff tank is equivalent

*From surface of sewage to bottom of tank.



Typical Section of Trickling Filter
Fitchburg, Mass. — Sewage Treatment Works.
Metcalf & Eddy - Consulting Engrs.
Boston Chicago.

Fig. 5.

to 4.59 cu. ft. per capita. The tanks have vertical side walls 18 ft. 5 in. in depth below which the bottoms of the tanks are constructed in the form of inverted pyramids 7 ft. 6 in. deep, three pyramids to each tank, making a maximum depth of 25 ft. 11 in. below the top. Each of the five tanks is divided into two compartments—a sedimentation compartment and a sludge storage compartment, by means of a cement-plaster partition wall, running longitudinally through the tank and forming three troughs in the width of each

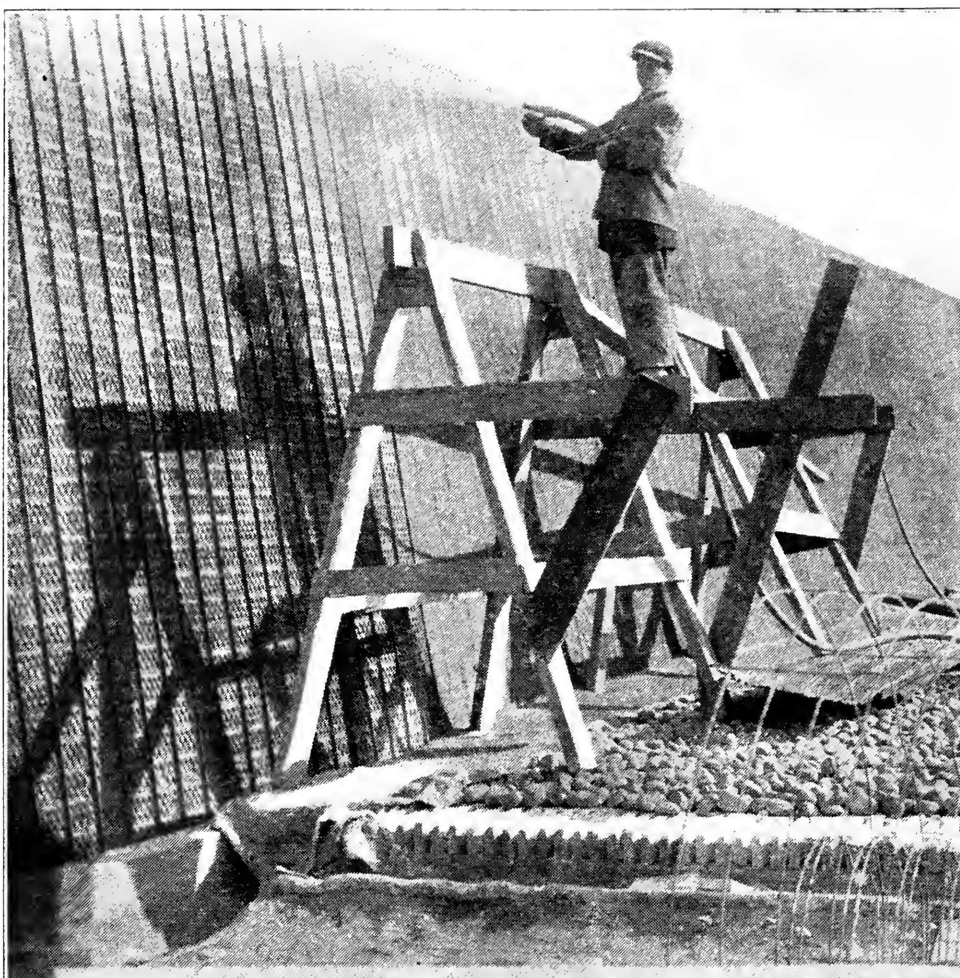
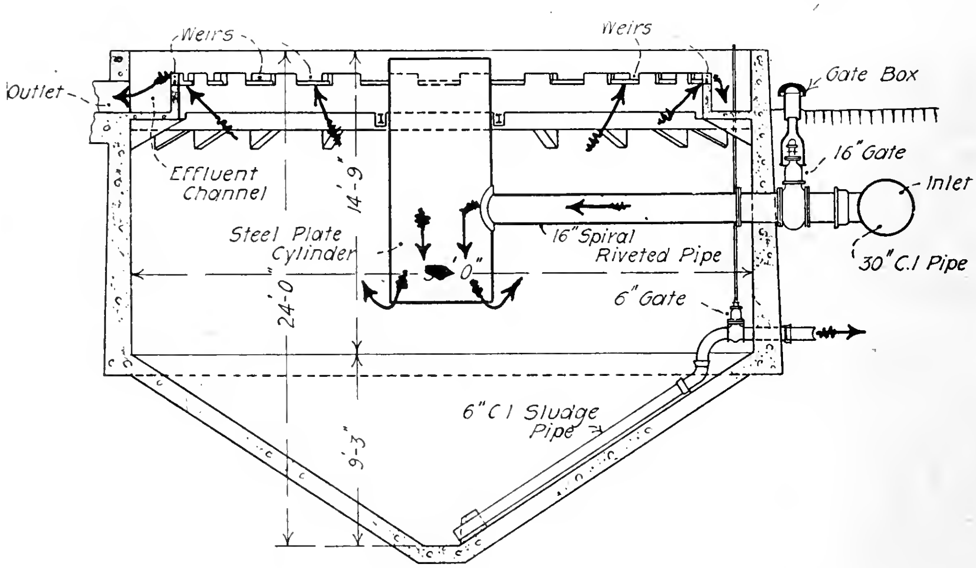


Fig. 6.

tank. The bottom of each trough terminates in a slot which allows solids settling out of the sewage, to pass through into the sludge storage compartment below, and is trapped to prevent the escape of gas.

Gas generated as a result of sludge digestion escapes by central and side gas vents, instead of passing up through the sewage flowing in the sedimentation compartment.

Each of the three hoppers in the sludge compartment of each Imhoff tank is provided with an air lift for removing the sludge. The advantage of this apparatus over the centrifugal or reciprocating pump is that the sludge is not broken up in its passage through the apparatus and the entrained gases are not liberated. If they were, the sludge would dry more slowly because it would be less porous. Compressed air is forced into the main riser pipe through a small air pipe entering at the side near the bottom. The compressed air accumulates until the specific gravity of the sludge contained in the pipe is decreased to a point below that of the liquid in the tank when the mass begins to rise. As the air approaches the surface it expands, due to the decrease in pressure, and the vertical velocity becomes greater, causing a continuous flow of



Typical Cross Section of Secondary Settling Tank
Fitchburg, Mass — Sewage Treatment Works.
Metcalf & Eddy—Consulting Engrs
Boston Chicago

Fig. 7.

sludge from the top of the pipe. This flow is maintained as long as the supply of air is maintained and the sewage in the tank is not drawn down below a critical point. This form of air lift is used extensively for pumping water, especially for irrigating purposes, but its use for lifting sludge is comparatively recent. From tests made on the air lift at the Fitchburg plant, it appears that where dense masses of sludge are encountered, which are too heavy to be lifted in the above-mentioned manner, the compressed air accumulates for a time, forcing pistons underneath succeeding masses, finally pushing them up and discharging them intermittently into the pipe line at the top. At Fitchburg, under normal operating condi-

tions, the lift from the surface of the sewage in the Imhoff tanks to the flow-line in the sludge pipe at the top of the vertical pipe, is 8½ ft.

Sludge Beds.—Open sand beds are provided for drying the sludge. They are in units 15 ft. wide by 111 ft. long, separated by partitions constructed of 2 in. creosoted planks 12 in. wide, set on edge and held in grooves in concrete posts. Each bed is served by a narrow gage track laid on the surface of the sand along the center line of the bed, with switches and a main track at the end of the beds leading to the sludge dump. The sludge, when sufficiently dry, is forked into the sludge dump, making it unnecessary to drive teams on to the sludge beds. This prevents injury to the beds, caused by teaming over them. The total area of sludge beds is 18,340 sq. ft., or 0.33 sq. ft. per capita. No underdrains were provided at Fitchburg, as the beds were built in a gravel deposit

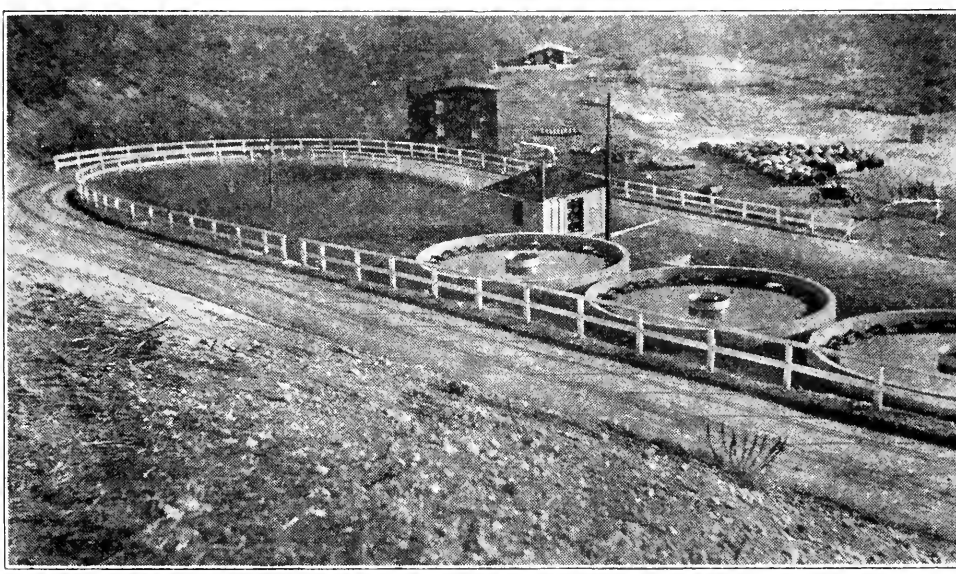


Fig. 8.

Secondary Settling Tanks.

high above the ground water. However, the estimates given herein include an underdrain pipe laid longitudinally in the center of each bed leading to a collector drain across the ends of the beds, as drains are likely to be required under many conditions.

Dosing Tanks.—The sewage after leaving the Imhoff tanks flows alternately into one or the other of two dosing tanks, each having a unit working capacity of 0.175 cu. ft. per capita. Each dosing tank is provided with automatic siphonic apparatus arranged to discharge the contents of the tanks alternately into the distribution system of the trickling filters. The dosing tanks are constructed so as to vary the volume discharged at the several heads

and produce a substantially uniform distribution of the sewage over the surface of the trickling filters.

Trickling Filters.—The trickling filters have been designed to serve 20,000 persons per acre, with the stone at least 10 ft. deep. Sewage is conveyed to the trickling filter from the dosing tanks, through a cast iron pipe distribution system, and sprayed on to the surface of the stones through nozzles placed at the apices of equilateral triangles having sides 15 ft. long. The maximum head on the spray nozzles is 8 ft., which is gradually reduced to a minimum of about 1 ft. in order to thoroughly distribute the sewage.

The crushed stone, which is between one and two inches in size, rests on a draining floor system of the type shown by Fig. 5. The concrete floor is constructed in the form of circular channels sloping toward the main drains. The channels are covered by

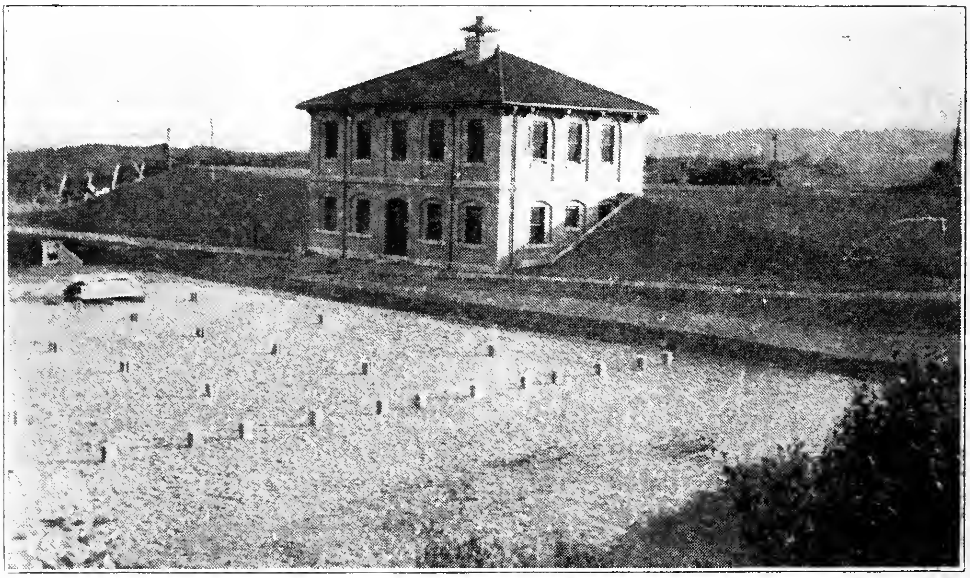


Fig. 9.

Sludge Beds.

rectangular slabs of cement mortar, laid on edge about one inch apart, so as to form a grating through which the sewage passes after trickling down through the stones. A flushing and inspection gallery is provided in the center of the filter, for use in cleaning out deposits of sand or humus, if any accumulate in the channels of the floor system.

The stone at the sides of the trickling filter is prevented from mixing with the gravel beyond, by thin partition walls constructed of cement plaster on metal lath. The partition is constructed on a slope, thus providing a greater area at the surface of the filter than at the bottom, so as to catch the outer portion of the spray from the filter nozzles.

Secondary Settling Tanks.—The typical trickling filter plant upon which the accompanying estimates are based, includes four sedimentation or humus tanks, each cylindrical in form, 30 ft. in inside diameter, with a conical bottom. The total depth to the bottom of the inverted cone, is 24 ft., the depth of the vertical side walls being 14 ft. 9 in. The aggregate working capacity is about 360,000 gal., equivalent to 0.85 cu. ft. per capita. The tanks are designed to furnish a sedimentation period of 1 hour, and to have a sludge capacity of approximately 0.15 cu. ft. per capita. They are of the vertical flow type. The water passes into a central distributing cylinder in each tank, thence downward and underneath its bottom edge, thence upward to and out over a number of weirs located around the side of the tank. The sludge accumulating in the bottoms of the tanks is regularly lifted, by a centrifugal pump, into the influent channel to the Imhoff tanks. Here the solids settle with the suspended matter of the raw sewage and pass into the sludge compartments, where they are subjected to bacterial action, to render them inoffensive.

Miscellaneous.—In addition to the main features of the trickling filter plant there have also been provided a suitable pumping equipment and building, air lifts for the sludge, air compressing equipment, a laboratory building suitable for housing the office, laboratories, store rooms and locker rooms for the men employed about the plant; also roads, water supply, electric light and other features necessary to make the plant complete and ready for operation.

ACTIVATED SLUDGE PLANT.

The plant for the activated sludge process has been designed as far as possible to meet the same conditions as those for which the trickling filter plant previously described was built. The same type of structures has been used where applicable, and an effort has been made in every way to make the two plants strictly comparable, both being designed to serve 55,000 persons.

Grit Chamber, Screens and Venturi Meter.—The grit chamber, screens and venturi meter equipment previously described for the trickling filter plant is included without change in the activated sludge plant, the requirements being the same in each case.

Sewage Aeration Tanks.—The sewage aeration tanks have been designed to operate on the continuous flow plan. The tanks are rectangular in plan, each unit being 30 ft. wide by 90 ft. long inside, of a type similar to the Imhoff tanks in the trickling filter plant. Compressed air is supplied to the tanks through a piping system leading to a series of filtros blocks located in the bottom of the tank. Each tank unit is divided by means of thin partition walls into four longitudinal channels 7 ft. 2 in. wide. Provision is made for a depth of 10 ft. of liquid above the top of the filtros blocks. It is intended to operate two tank units in series and five double tank

units in parallel; that is, the sewage will enter one tank, pass longitudinally back and forth through the four channels in that tank, then to the second tank and back and forth longitudinally through the four channels of that tank to the point of discharge, making a total distance travelled of about 700 ft. Sufficient tank capacity is provided for an average period of aeration of 4½ hours, with sludge capacity amounting to 25% of the total tank capacity. Under these conditions the average horizontal velocity will be about 2.6 ft. per minute. The ratio of total tank floor surface to area of aerating system is 8.5 to 1, which is the basis of the present Milwaukee tanks. The indications are, however, that this ratio should be reduced so as to provide a somewhat larger area for air diffusion.

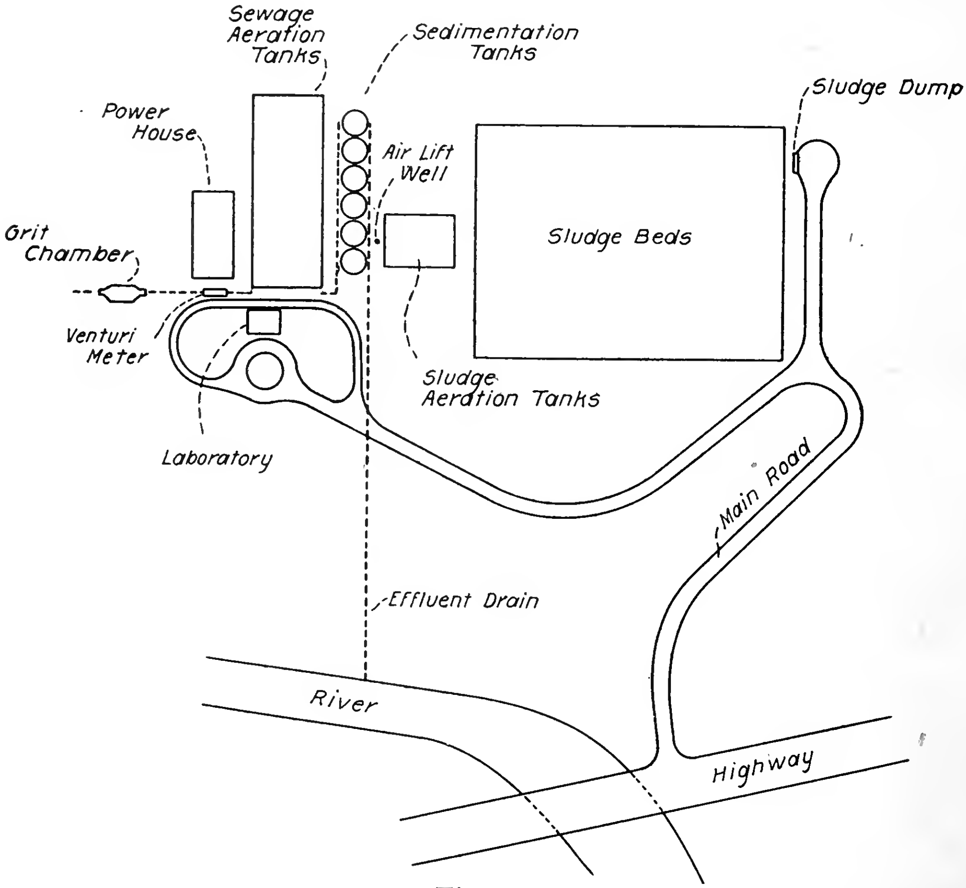


Fig. 10.

Plan of Typical Activated Sludge Plant for Sewage Treatment.

For the purpose of aeration and agitation it is assumed that the volume of air to be supplied will average 1.75 cu. ft. per gal. of sewage treated.

Air Compressors.—The quantity of air required to aerate the average quantity of sewage at the rate of 1.75 cu. ft. per gallon treated, will be 6,680 cu. ft. per minute. An increase in rate of sewage flow to 150% of the average will frequently occur and the

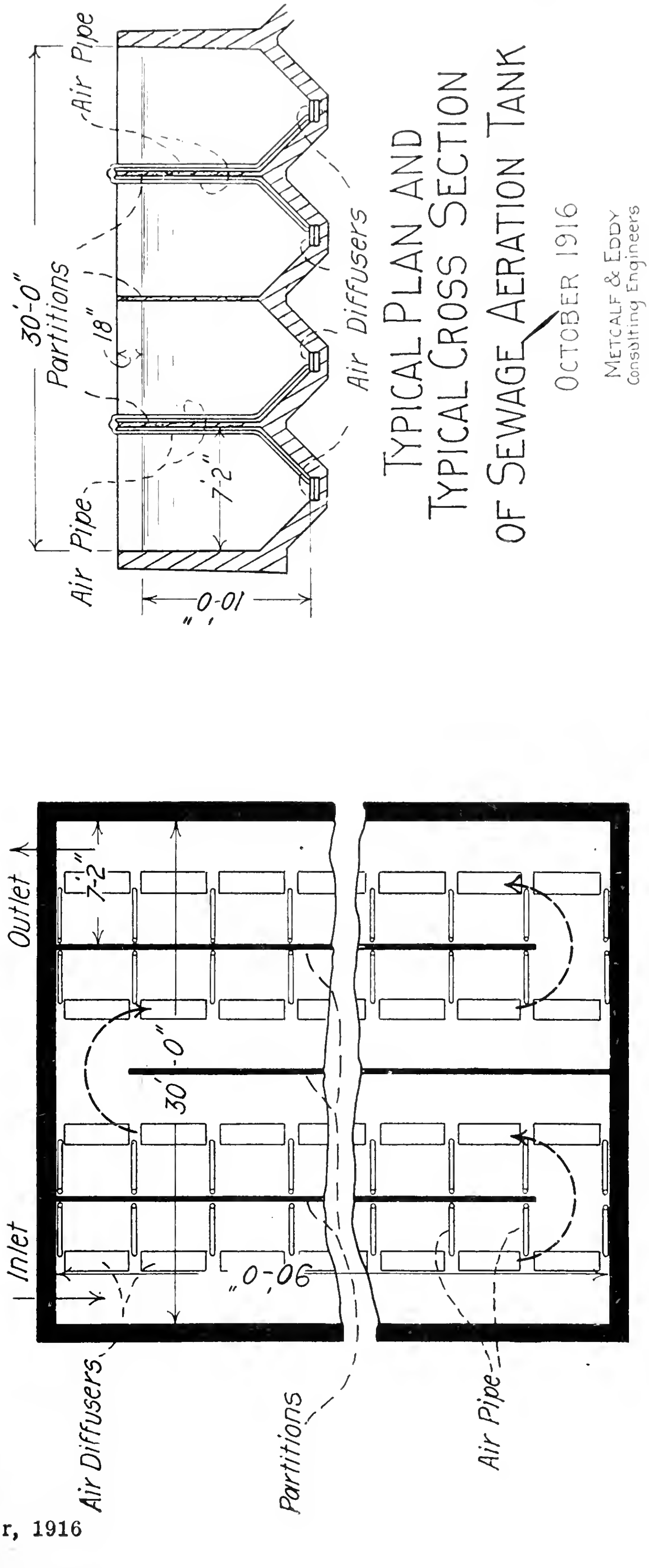

Air Pipe
30'-0"
Partitions
18"
7'-2"
Air Diffusers
10'-0"
TYPICAL PLAN AND
TYPICAL CROSS SECTION
OF SEWAGE AERATION TANK
OCTOBER 1916
METCALF & EDDY
Consulting Engineers
BOSTON - CHICAGO
Outlet
Inlet
7'-2"
30'-0"
90'-0"
Air Diffusers
Partitions
Air Pipe

Fig. 11.

air compressing plant must be able at all times to meet this requirement. In addition, provision must be made for emergencies of various kinds. For this service four units of electric, motor-driven, positive pressure blowers, are provided, each capable of furnishing about 3,200 cu. ft. of free air per minute at a pressure of about 5 lb. per sq. in. The motors must be of the variable speed type, in order that the quantity of air may be varied according to the requirements. Two additional blowers of the same type and size are provided, to furnish air for the sludge aeration tanks.

There are three types of air compressors available for service of this character—the positive pressure blower, the centrifugal compressor and the reciprocating compressor. For units of the capacity outlined above, the positive pressure blower driven by a variable speed electric motor, offers the cheapest form of apparatus, and where the pressure to be furnished is 5 lb. per sq. in., or even as high as 8 or 9 lb. per sq. in., good efficiency can be obtained. The discharge of air is not steady, but comes in pulsations depending upon the number of impellers in the machine. Centrifugal compressors run at a much higher speed, roughly 3,500 r. p. m., instead of 200 r. p. m., furnish a steady flow of air, and permit easy regulation of the quantity of air without serious loss of power, by simply throttling the discharge. The positive pressure blower, on the contrary cannot be so easily regulated, as the quantity of air can only be varied by changing the speed of the machine, or by wasting air. The centrifugal compressors occupy much less space for the same volume of air furnished, and probably a smaller number of units will suffice. Except for units of large volume and for pressures of 10 lb. per sq. in. or greater, the first cost of the centrifugal compressor is materially more than that of the positive pressure blower. Probably somewhat higher efficiencies can be obtained with the centrifugal compressor.

A reciprocating compressor is usually built for pressures materially in excess of those which will ordinarily be required for activated sludge work. Such machines of large capacity and for low pressures, say 5 to 10 lb. per sq. in., are not well adapted to the work, but for higher pressures, they may be used, although at a somewhat greater expense than the centrifugal compressors.

One disadvantage of the reciprocating compressor is that the air discharged may contain oil, which is liable to cause clogging in the filtros blocks or other air diffusers. The internal parts of the positive pressure blower and centrifugal compressors do not require lubrication, so that the air discharged from these machines should be free from oil.

Air Washer.—On account of the small pores in the diffusing system, whether filtros blocks, wooden blocks or other means are employed, it is essential that the air furnished shall be clean, that is, free from dust, oil or other foreign substances. One of the best methods of obtaining clean air is to pass it through an air washer

before going to the compressor. Such apparatus is a standard commercial product and operates satisfactorily.

Measurement of Air Volume.—It is essential to know the quantity of air supplied to the diffusing system if the plant is to be operated most intelligently. Several forms of air measuring apparatus are available. The estimates provide for two air flow meters of the General Electric Company type, similar to those in use at the Milwaukee plant. One of these meters is intended to measure the quantity of air supplied to the sewage aeration tanks, and the other the air supplied to the sludge aeration tanks. In a large plant it may be advisable to install additional meters to measure the quantity of air supplied to air lifts, but in this comparison no allowance is made for such additional apparatus.

Power House.—A building will be required to house the several air compressor units amounting, in this particular case, to six large positive pressure blower units and two small reciprocating units for operating the air lifts. This building may also house the air washer, air meters, transformers and other equipment.

Sedimentation Tanks.—The effluent from the sewage aeration tanks will contain a large quantity of suspended matter, which must be removed by sedimentation. The estimates include six sedimentation tanks. Each is of the vertical flow type, cylindrical in form with inverted conical hopper bottom terminating in a deep well 4 ft. in diameter, similar to the tanks at Milwaukee. The tanks provide for sedimentation for a period of ½ hour, on the continuous flow plan, with space for sludge amounting to 25% of the total tank capacity. The total depth of water and sludge, in the central wall, is 35 ft. The tanks at Milwaukee were constructed with hopper bottoms on a slope of 1 to 1, but experience has proven that steeper slopes are necessary if the sludge is to slide easily into the central well. These tanks are so designed that the sewage and sludge will enter the tank at the center, flow downward and under the edge of the distributing cylinder, thence upward and out through collecting weirs arranged around the circumference of the tank. Each of the central sludge wells will be provided with an air lift to raise the sludge from the sedimentation tanks to the sludge aeration tanks, or into the influent of the sewage aeration tanks.

Sludge Aeration Tanks.—Two units of sludge aeration tanks are provided of a type similar to the sewage aeration tanks, but differing in that the partition walls are made heavy enough to withstand water pressure, thereby making each channel a separate subunit. The general dimensions of channels are the same as in the sewage aeration tanks; that is, 7 ft. 2 in. wide and 90 ft. long, provision being made for a depth of 10 ft. The total capacity of sludge aeration tanks provided is 328,000 gal. which is equivalent to 0.8 cu. ft. per capita, or about 60,000 gal. per million gallons of operating capacity.

Air Lift Pumps.—It is planned to provide one such lift in a

well to serve the eight sub-units of sludge aeration tanks, and a similar lift for each of the sedimentation tanks. As already stated, these pumps have the advantage of handling the sludge without breaking up the flocculent particles, which is necessary to the success of the activated sludge process.

Sludge Beds.—It is estimated that the activated sludge process will produce about 4,500 gal. of sludge per million gallons of sewage. Doubtless this quantity will vary considerably under different conditions. It is largely dependent upon the proportion of water contained in the sludge. For the average quantity of sewage for which this plant is designed, 5,500,000 gal. per 24 hours, the quantity of sludge produced daily will be 24,750 gal. For the purposes of this comparison it is assumed that the sludge will be dried on sand drying beds from which it can be removed to a dump.

It is recognized that important experimental work is being done to develop suitable dewatering and drying processes that will make it economically possible to dry the sludge to 10% moisture and thus make it saleable as a low-grade fertilizer or as fertilizer base. Analyses reported by William R. Copeland, chief chemist of the Milwaukee Sewerage Commission, in a recent paper before the American Chemical Society, indicate that activated sludge contains a much higher percentage of nitrogen than the sludge from other processes such as plain sedimentation, chemical precipitation, the septic tank and the Imhoff tank. The preparation of this material for fertilizer is still in the experimental stage, and it is too early to make positive assertion regarding the cost of this work. There are, however, some promising indications and it may be that the disposal of sludge may become a self-supporting part of the process or even produce a revenue which will help pay the cost of other portions of the plant.

For the purpose of estimates it is assumed that the sludge drying beds can be dosed an average of 15 times per year to a depth of 12 in., thus requiring a total net area of sludge beds of 80,500 sq. ft. To this should be added a sufficient area to care for sludge during the winter months (Dec. 15 to March 15) and allow for drawing of water collecting on the surface of the sludge. To provide for these contingencies the area should be increased 50% to 120,750 sq ft., equivalent to 2.76 acres net area, or 2.2 sq. ft. per capita. If sludge bed units of the same size and type as described for the trickling filter plant, are used, there will be required 77 such units, or about 7 times the area required for the trickling filter process. These sludge beds are suitably underdrained and provided with a system of narrow gage tracks and cars for removing the sludge to the sludge dump when it can be carted to a point of disposal.

COST OF CONSTRUCTION.

The cost of the trickling filter plant, as already stated, has been based on the unit costs of construction of the trickling filter plant at

Fitchburg, Mass., which was built by contract, bids being received in May, 1913. Cost figures obtained in this way are more nearly representative of normal conditions than if based on the high cost of construction prevailing at the present time. As far as possible the same unit costs of construction have been applied to the estimates of the activated sludge plant, that the two estimates may be comparable.

Trickling Filter Plant.—The estimated cost of the trickling filter plant is given in Table 1. In addition to the main features already described, a number of items are included which go to make up the complete plant. It should be noted that the amount included for cost of land, includes not only the land required for the treatment plant, but a total area of about 117 acres, sufficient not only for all purposes of sewage treatment but also more than sufficient to properly isolate the plant. Under miscellaneous work are included such items as extension of the water supply, electric lighting system, and other features of minor importance not covered by the principal items. It is expected that for a plant of this character administration charges may easily amount to 3% and engineering to 12%, making a total of 15% to be added for these items. The total estimate of the Imhoff tank—trickling filter plant for a city of 55,000 population, is $431,710. This is equivalent to $7.85 per capita, or $78,500 per million gallons per day for the assumed flow of 5.5 mil. gal.

TABLE 1.

ESTIMATED COST OF IMHOFF TANK-TRICKLING FILTER PLANT.

	Cost Excl. Eng'g. and Administration Total	Unit Cost. Excl. Eng'g. and Administration	
		Per Capita	Per M. G. D.
Grit and Chamber Screen	$ 10,000	$0.18	$ 1,818
Venturi Meter Chamber	3,000	.05	545
Imhoff Tanks incl. Air Lifts for Sludge	64,500	1.17	11,720
Air Compression Equipment	800	.01	145
Sludge Beds incl. underdrains	4,800	.09	873
Trickling Filters 10 ft. Deep (2.75 acres)	188,500	3.43	34,300
Dosing Tanks and Apparatus	16,600	.30	3,020
Secondary Settling Tanks	9,000	.16	1,637
Sludge Pumping Equipment and Building	2,000	.04	364
Conduits and Pipe Lines, incl. Overflow	10,600	.19	1,925
Effluent Channel	1,300	.02	236
Roadways	9,100	.17	1,655
Laboratory Building and Equipment	15,200	.28	2,762
Grounds, Trees, Planting, etc	1,700	.03	309
Miscellaneous Work, 4% of total, excl. land	13,300	.24	2,420
Land	25,000	.45	4,550
Total	$375,400	$6.81	$68.279
Add 15% for Engineering and Administration	56,310	1.04	10,221
Grand Total	$431,710	$7.85	$78,500

For 55,000 persons = $7.85 per capita.
For 5,500,000 gal. per day = $78,500 per m. g. d.

Activated Sludge Plant.—The estimated cost of the activated sludge plant is given in Table 2. In addition to the features already described, it will be noted that several items have been included to make the plant complete. As stated in the case of the trickling filter plant, the item of $25,000 for land includes about 117 acres. It may not ultimately prove necessary to isolate the activated sludge plant, in which case a credit in favor of this plant should be made on account of the small area of land required. In this case, as in the other, 15% has been added to cover the cost of administration and engineering charges. It will be seen that the total cost of the activated sludge plant is $313,880, which for a population of 55,000 persons is equivalent to $5.71 per capita, and $57,100 per million gallons per day.

TABLE 2.

ESTIMATED COST OF ACTIVATED SLUDGE PLANT.

	Cost Excl. Eng'g. and Administration Total	Unit Cost. Excl. Eng'g. and Administration Per Capita	Per M. G. D.
Grit Chamber and Screen	$ 10,000	$0.18	$ 1,818
Venturi Meter and Chamber	3,000	.05	546
Sewage Aeration Tanks	78,100	1.42	14,200
Sludge Aeration Tanks incl. Air Lifts	17,500	.32	3,180
Sedimentation Tanks, incl. Air Lifts	8,300	.15	1,510
Air Compressing Equipment	22,600	.41	4,110
Air Meters—2	700	.01	127
Air Washer—1	600	.01	109
Power House	29,700	.54	5,400
Sludge Beds incl. Underdrains	31,400	.57	5,710
Conduits, Pipe Lines and Overflow	10,000	.18	1,818
Effluent Drain	1,300	.02	236
Roadways	8,300	.15	1,510
Laboratory Building and Equipment	15,200	.28	2,760
Grounds, Trees, Planting, etc	1,700	.03	309
Miscellaneous Work, 4% of total, excl. land	9,540	.17	1,735
Land	25,000	.45	4,540
Total	$272,940	$4.94	$49,618
Add 15% for Eng'g. and Administration	40,940	.77	7,482
Grand Total	$313,880	$5.71	$57,100

For 55,000 persons = $5.71 per capita.
For 5,500,000 gal. per day = $57,100 per m. g. d.

COST OF OPERATION.

Trickling Filter Plant.—An estimate has been made of the cost of operation of the trickling filter plant, based principally on the experience at Fitchburg, for the years 1915 and 1916. From data furnished by David A. Hartwell, Chief Engineer, deductions have been made for certain expenditures pertaining to construction rather than operation. The items for 1916 (with estimates for November, the last month of the fiscal year) are shown in Table 3, from which it appears that the total cost of operation has been $11,250, which is equivalent to $10.28 per million gallons treated, averaging 3 m. g. d.,

or 35c per capita, on a basis of 32,500 persons actually connected. The total population in 1915 was about 39,656.

Similar figures for the Gloversville trickling filter plant, obtained through the courtesy of Harry J. Hammer, City Engineer, show the following costs of operation per million gallons of sewage treated:

	Annual Cost of Operation	
Year	Per M. G. Treated	Per Capita
1913	$5.16	$0.24
1914	5.92	.27
1915	5.72	.26

It should be stated here that these expenditures are limited to the barest necessities. No chemical supervision nor other refinements which can be avoided, are permitted.

The estimate of annual operation cost of the hypothetical Imhoff tank-trickling filter plant to serve a population of 55,000 is given in Table 4.

TABLE 3.

ESTIMATED ANNUAL COST OF OPERATION OF FITCHBURG, MASS., IMHOFF TANK-TRICKLING FILTER PLANT, FOR THE YEAR 1916.

General, incl. Administration	$ 1,800
Laboratory	1,700
Grit Chamber	900
Imhoff Tanks	1,700
Trickling Filters	1,100
Secondary Tanks	900
Sludge Beds	800
Care of Grounds	1,250
Miscellaneous	1,100
Total	$11,250

3 m. g. d. = 1,095 m. g. treated = $10.28 per m. g.
32,500 persons = $0.35 per capita.

TABLE 4.

ESTIMATED ANNUAL COST OF OPERATION OF TYPICAL IMHOFF TANK-TRICKLING FILTER PLANT.

General, incl. Administration	$ 2,200
Laboratory	1,700
Grit Chamber	1,650
Imhoffff Tanks	3,120
Trickling Filters	2,020
Secondary Tanks	1,650
Sludge Beds	1,470
Care of Grounds	1,250
Miscellaneous	2,020
Total	$17,080

5.5 m. g. d. = 2,005 m. g. treated = $8.50 per m. g.
55,000 persons = $0.31 per capita.

Activated Sludge Plant.—The estimated annual cost of operation of the activated sludge plant is shown in Table 5. Nearly half of the annual operating cost is for electric power, required for com-

pressing the air. It was estimated that in addition to the air required for sewage aeration one-fifth as much would be required for sludge re-aeration and for operating the air-lift pumps. The total annual cost of operation amounts to $40,140 which is equivalent to $20 per million gallons treated, or 73c per capita, based on 55,000 persons.

The item for power is estimated on the assumption that it can be obtained at 1c kw. h. For many places this is a low price, while for others it is high. Surely it is low enough for use in computing the cost of power in most places upon a project which is to be operated for a generation in the future.

TABLE 5.

ESTIMATED ANNUAL COST OF OPERATION OF TYPICAL ACTIVATED SLUDGE PLANT.

Item.		Annual Cost.
General, incl. Administration		$2,200
Laboratory		1,700
Grit Chamber		1,650
Tank Treatment—		
1 Engineer foreman at $4 per 8 hr. day, 312 days	$1,248	
3 Engineers at $4	3,744	
4 Laborers at $2.50	3,120	
Repairs	1,278	9,390
Sludge Drawing and Disposal—		
Foreman part time	$ 375	
2 Laborers at $2.50, 312 days ea	1,560	
1 Team at $6, 312 days	1,872	
Supplies and Repairs	603	4,410
Electric Power at 1c per kw. h		17,040
Care of Grounds		1,250
Miscellaneous		2,500
Total		$40,140

5.5 m. g. d = 2,005 m. g. treated = $20.00 per m. g.
55,000 persons = $0.73 per capita.

COMPARISON OF COSTS.

For the final comparison of costs the interest and depreciation have been computed for both plants, and the total annual cost, made up of operating expenses and interest and depreciation, has been capitalized at 4% and added to the construction cost, Table 6. The result is decidedly in favor of the Imhoff tank-trickling filter plant, in spite of the fact that the estimates of operation of the activated sludge plant have been kept low, probably lower than is justified, that there might be no danger of inflating this cost to the disadvantage of the new process. To eliminate this difference it will be necessary to decrease the operating expenses of the activated sludge treatment by about $11,000, or to decrease them a portion of this amount and in addition thereto to decrease the construction cost materially.

TABLE 6.

COMPARISON OF COSTS OF IMHOFF TANK—TRICKLING FILTER PLANT AND ACTIVATED SLUDGE PLANT.

Item.	Trickling Filter Plant.	Activated Sludge Plant.
Operating Expenses	$ 17,080	$ 40,140
Interest and Depreciation*	26,760	19,780
Total Annual Cost of Treatment	$ 43,840	$ 59,920
Total Annual Cost of Operation per m. g.	21.84	29.85
Total Annual Cost of Operation per capita	0.80	1.09
Expenses capitalized at 4%	$1,096,000	$1,498,000
Construction Cost	431,710	313,880
Total	$1,527,710	$1,811.880
Difference		284,170

A reduction in the price of power from 1c to .6c per k. w. h., the price at which it is estimated power can be purchased at Milwaukee, would effect an anual saving of $6,816. For a plant only large enough for 55,000 persons it is doubtful if power below 1c per k. w. h. can be procured in many places.

It is not unlikely that improvements in the methods of diffusion and of holding the air for a longer time in contact with the sewage may result in a decrease in the quantity of air required. This would result in a decrease in cost.

At the present time much attention is being given to methods of converting the sludge into marketable fertilizer. There is reasonable agreement among investigators that activated sludge contains a greater proportion of fertilizing ingredients than the sludges obtained from most other processes of sewage treatment. If the sludge can be converted into commercially dry powder containing only 10% moisture, there is good evidence of a market for it at a moderate price.

If the cost of preparation and sale of sludge should be no more than the return from such sales, the reduction in the foregoing estimates of operation and construction would be $5,030 and $36,000 respectively. If this process should be even more successful and a net profit of $2.00 per ton or say $1.00 per million gallons should be derived, the saving thus effected would amount to—

Profit on sludge	$2,007.50
Cost of sludge disposal as per previous estimate	5,030.00
Interest and depreciation on sludge beds.	2,270.00
Total	$9,307.50

In addition to this annual saving there would be also the saving in investment cost of $36,000.

Even this profit and saving would not be enough to reduce the

*Interest at 4%—Depreciation—Sinking fund at 2½%.

cost of the activated sludge process to that of the Imhoff tank-trickling filter process, but the net phofit of $1.00 per million gallons may be substantially exceeded. In any event, this subject should receive, as indeed it is receiving, most careful investigation.

It may be argued that greater economy will be possible in the large plants than in the typical plant designed to serve 55,000 persons. This is undoubtedly true, but it is also true of the trickling filter plant. The proportionate saving in the cost of the activated sludge plant, however, may be somewhat greater.

Further development, particularly in the direction of reducing the quantity of air required, and improving means of distribution, may result in a reduction of construction cost. It seems more probable, however, that the cost of construction will be increased, and in any event there should be no reduction in construction cost at a sacrifice in efficiency.

In spite of the fact that it appears to be somewhat more expensive than other processes, the activated sludge treatment should not be rejected on the ground of cost without giving full consideration to its advantages. It may be that as an oxidizing process it will always be more expensive than the trickling filter, but it may have advantages more important than this disadvantage.

ADVANTAGES AND DISADVANTAGES OF THE TWO PROCESSES.

Relative Areas of Land.—If it is assumed that the sludge from the activated sludge process is to be dried and disposed of by means of sludge beds, the total area of land used for the activated sludge plant will not differ greatly from that actually used for the trickling filter plant.

The areas utilized for several trickling filter plants, including a reasonable allowance for walks, drives and general purposes, are shown in Table 7.

TABLE 7.

Location of Plant.	Area of Land Required for Plant Acres.	Area of Trickling Filters.	Average Depth of Stone in Trickling Filters.
Fitchburg, Mass.	11.8	2.07	10′ 3″
Schenectady, N. Y.*	19.0	6.1	4′ 7½″
Gloversville, N. Y	13.5	3.07	4′ 7½″
Typical trickling filter plant, estimated	11.8	2.75	10′ 3″

The estimated area required for the typical activated sludge plant is 10 acres, or nearly 2 acres less than that required for the typical trickling filter plant. If some other form of sludge disposal were used, the area would be materially reduced. In the second annual report of the Milwaukee Sewerage Commission, it is stated that the ground area required for the Milwaukee activated sludge plant is 0.4 acre. This plant is capable of treating 1,620,000 gallons of sewage per day, but the area given makes no provision for sludge

*Original design; only one-half plant built.

disposal and practically nothing for walks, drives and other features to be expected in an ordinary, complete plant. As already stated, the activated sludge plant may have some advantage in not requiring as much land for isolation as the trickling filter plant. The corresponding reduction in cost would be to the advantage of the former.

Loss of Head Necessary in Plant.—One of the important advantages of the activated sludge process is the small loss of head required for the passage of the sewage through the plant. The resulting saving in cost of sewerage works such as pumping stations and long outfall or intercepting sewers, may be sufficient to make the adoption of the activated sludge process imperative. The amount of head lost in several trickling filter plants is shown in Table 8.

TABLE 8.

HEAD LOST IN TRICKLING FILTER PLANTS.

Location of Plant.	Head Lost Ft.
Columbus, Ohio	25.34
Fitchburg, Mass.	25.40*
Gloversville, N. Y.	21.40
Schenectady, N. Y. (original design)	13.70
Schenectady, N. Y. (actual construction)	14.65
Washington, Pa.	16.50
Philadelphia, Pa.	25.25
Atlanta, Ga., Peachtree Creek Works	20.00

From this table it will be seen that the head required for a trickling filter plant varies from 14 ft. to a little over 25 ft. The Milwaukee 1.62 m. g. plant requires 0.3 ft. between the inlet to the sewage aeration tanks and the outlet of the sedimentation tank. In addition to this some loss should be added for the grit chamber and screens, but in any event, a total loss of 1 to 2 ft. would appear to be ample.

Odors. There is some sentiment hostile to an Imhoff tank-trickling filter plant because of the fear of the dissemination of objectionable odors. That objectionable odors are noticeable in the immediate vicinity of such plants cannot be denied. On the other hand, there is good evidence that they are not noticeable except very close to the treatment plants.

The activated sludge plant appears to have some advantage in this direction. Odors may be noticeable in the immediate vicinity of the aeration tanks, and it is possible that objectionable odors may be given off from some portions of the sludge drying and handling process, whatever it may ultimately be. It is probable, however, that the danger from this source will be less than from the Imhoff tank-trickling filter plant.

Moth Flies. The moth flies, so prevalent at certain seasons of the year, are quite objectionable close to the filters, although they are rarely found more than a few hundred feet away from

*Actual is 42.1 due to topography.

them. While this cause of annoyance may be kept under reasonable control, it is doubtful if it can be wholly eliminated. The activated sludge plant does not seem to be a suitable breeding ground for these pests, and therefore has an advantage over the filter.

Quality of Effluents.—There is no doubt that the activated sludge process is capable of producing a more highly oxidized effluent than the trickling filter, as ordinarily built and operated, that it will eliminate a much greater proportion of bacteria, and that in appearance its effluent will be decidedly superior to that of the filter. This is a marked advantage under certain circumstances, but these facts alone should not be allowed to control in the adoption of a more expensive process when the accomplishments of the trickling filter answer all purposes.

Such a course would be like purchasing an article one does not want simply because it is cheap.

Complexity of Activated Sludge Process.—A disadvantage of the activated sludge process in the minds of many who have studied it is its apparent complexity and need for careful and skillful supervision. While it has been contended by some that this process is exceedingly simple and one which can be operated by a workman of ordinary intelligence, the consensus of opinion appears to be to the contrary. The author's experience in operating several small experimental plants, leads him to feel that of all processes of sewage treatment in practical use in this country today this is by far the most difficult to operate and that it will require the skill of a well trained engineer or chemist to insure continued satisfactory results with it.

THE ACTIVATED SLUDGE TREATMENT OF INDUSTRIAL WASTES.

Many of the problems of industrial wastes treatment are similar in character to those of the treatment of municipal sewage. Most such wastes contain organic matter which must be oxidized by bacterial action before they can properly be discharged into small water courses or into other waters where dilution is restricted.

Where wastes are free from chemicals inimical to bacterial life, the organic matter contained in them can be oxidized by the ordinary processes of sewage treatment. The trickling filter has been repeatedly found to be capable of carrying on such oxidation.

During the past year investigations have been made under the writer's direction of the activated sludge process as a means of oxidizing the organic matter in tannery, paper mill and woolen mill wastes. All of the tests have met with some degree of success. The tannery wastes appear to be particularly well adapted to this treatment.

At a sheepskin tannery, where the wastes are several times as strong as ordinary municipal sewage, a satisfactory, effluent, entirely stable, free from suspended matter, and with very slight

turbidity, was produced with the expenditure of 10 cubic feet of air per gallon of wastes. The period of aeration was 12 hours, and in the winter, the wastes were artificially heated to about 70° Fahrenheit, to facilitate the tests. Whether or not it will be necessary always to heat the wastes during winter has not been determined, but it is not anticipated.

The woolen mill wastes were very susceptible to the activated sludge treatment. A clear, stable effluent can be produced, but the quantity of air which will be necessary to achieve this result has not yet been determined.

CONCLUSIONS.

At the present time it appears that the Imhoff tank-trickling filter process is a less expensive means of oxidizing the organic matter of sewage and industrial wastes than the activated sludge process, where oxidation alone is considered. If the areas of land required for isolation, the loss of head in the plant, the danger of objectionable odors and of the fly annoyance, and other disadvantages of the trickling filter process are of marked importance in any specific case the balance may be decidedly in favor of the activated sludge process, even in its present state of development.

The activated sludge process should receive, and is having, much study. There are many problems connected with it which may be solved in such a way as to put it in a much more favorable position. It is to be seriously hoped that investigations will go forward until the process is thoroughly perfected. In the meantime, also, further attention should be given to improvement in the design and operation of the older processes of sewage treatment.

DISCUSSION.

John W. Alvord, M. W. S. E.: I have been very much interested in the presentation of this comparison between the Imhoff trickling filter and activated sludge methods of sewage treatment. It is a subject which is a very live one just now, and a problem in which we are obliged to presuppose data for our judgment in many cases pending the development of further reliable information.

I am interested to observe that the operating costs for the existing Fitchburg plant, with the Imhoff trickling filter method, and the operating costs for the hypothetical activated sludge plant, equal in capacity, closely approximate the earlier operating costs of the Worcester chemical precipitation plant, with its final sand filtration stage, which Mr. Eddy so long operated in early days. I remember noting the costs of the early Worcester plant with a great deal of interest, and they ranged, if I remember rightly, very close to about 35 cents per capita per annum, as seems to be the case with the plants under discussion tonight. So it would appear that although these improvements which have come up for consideration are novel, and, to some of us, new and striking, the cost of

sewage disposal has not materially changed after all, unless it may be claimed, as I think it may, that we get better effluents for our money.

It has been one of my interests to follow fairly closely the art of sewage purification for the past twenty years—perhaps longer, and I should say during that time that three and perhaps four times there have been somewhat authoritative announcements of new and novel processes, which were to revolutionize the art, so that apparently everything of the old practice was to be forgotten, and the great problem would be newly and efficiently solved. I am a little skeptical, I am free to confess, as time goes by, as to these waves of enthusiasm that one finds from time to time for new methods in sewage purification, and as I look back to the past I think we knew a good deal about sewage purification fifteen of twenty years ago, and accomplished a good deal. We had fairly efficient tanks, followed by various types of filters—sand filters, artificial filters, and land—which, when well designed and operated, produced good effluents for a reasonable sum of money. We had the sludge problem with us then, and we have the sludge problem with us today, and it cannot be said that the sludge problem has yet been solved, especially for very large plants.

The fatal thing about sewage purification, and the thing that has always defeated us, has been that our city administratives and sanitary authorities do not live up to our technical knowledge of operating problems in sewage plant management after the plants are built and in operation. We have never succeeded, except in a few isolated cases, in getting from municipal governments appropriations, attention, care and intelligent technical supervision of sewage plant operation, which they absolutely need and which they must absolutely have to be successful. If some of our earlier plants had had this operating care and attention that some of the exceptional plants, such as Mr. Eddy has described at Fitchburg, seem to have, I am quite confident that they would have in their day shown most excellent results.

I am not, however, a pessimist on sewage purification processes. All intelligent labor, experiment and discovery in sewage plant design give us larger and larger means for coping with that most difficult problem; they increase our resources and they advance and expand our knowledge, and what is a very real difficult problem becomes constantly more capable of being well handled.

I think, therefore, that the activated sludge method as a working idea, is going to greatly help us in the future in dealing with difficult problems in special cases. But I have not the enthusiasm that would make me feel that it is going to revolutionize the art altogether, or abolish many original and valuable ideas which have been developed in the past.

Edward Bartow: Mr. Eddy's paper is encouraging to those experimenting with activated sludge. We have been feeling rather discouraged in our work at the Illinois State Water Survey Experi-

ment Station. We have to pay 2.1 cents per k. w. for current, and the bills are rather high. We are hoping to increase the efficiency in obtaining the air, thus reducing the cost at the present time. We are making experiments with air diffusers and are planning schemes for de-watering the sludge.

Our plant was designed to handle 200,000 gallons per day, but owing to the small settling chamber, we have not been able to get as much as that through the plant. We used the septic tank, which was built under Professor Talbot's direction in 1897, for the city of Champaign. We made the aeration chamber as large as possible, using filtros plates covering about one-fourth of the area of the bottom of the tank, We made the settling chamber as large as possible between the end of the tank and the end of the building. It gives us a settling capacity of only about eighteen to twenty minutes.

Our first experiments were run with a view of obtaining a clear effluent. And with our plant we could get 60,000 to 75,000 gallons of a clear and stable effluent. Having convinced ourselves that the settling capacity was too small and that we could not do better without enlarging the settling tanks, we changed our method of procedure, and for the last month we have been running the plant at the rate of 150,000 gallons per day, using about two cubic feet of air per gallon. Sludge was carried over with the effluent, so that samples tests were obtained by secondary settling in glass cylinders. We have been handling 150,000 gallons and getting an effluent that makes us feel quite encouraged with regard to the capacity of our little plant.

We have made plans to compare air diffusers in our four concrete tanks. Through the courtesy of Mr. Hatton, we have obtained for our tanks some of the wooden blocks which he is using. In the second we expect to use pipes with holes such as have been used at the Stock Yards. In the third and fourth will be two grades of filtros plates. In our four tanks we can use a uniform quality of sewage and uniform aeration. The only difference will be the differences in the diffusers. We are hoping to get some comparative results which should be better than can be obtained by comparing results from different plants.

Our sludge drying experiments have not amounted to anything as yet, as the promised apparatus has not been received. As soon as it comes we are expecting to try some experiments which will be suitable for comparison with those obtained at Milwaukee, by their sludge presses, and at Cleveland by their centrifugal machine.

Langdon Pearse, M. W. S. E.: Our experience has been with a different character of sewage, a good deal stronger than that described by Professor Bartow or any one else, or that is being handled in Milwaukee. Consequently the amount of air that we use is somewhat larger. We have been running about four cubic feet

of air to the gallon,—sometimes five, through a period of eight hours' aeration. We are hoping to cut that down somewhat.

We have a large amount of sludge, very watery, that will have to be handled by secondary decantation before it can be pressed. The problem is going to be one of quantity with us, because on the comparison with Imhoff tanks with domestic sewage we obtain about ten times as much sludge. We have been working differently from other experimenters in that most of our work has been with the use of a 30 mesh screen. Our previous experiences would indicate that we should take out about one-quarter of the settling solids, as compared with the three-quarters which would settle out afterwards. This ratio would be somewhat different on the activated sludge process because we are probably getting more solids out than we could by settling. We have been operating the screen continuously, except at night and Sundays, and find that it is a help in taking out much material that really has no use in the tanks and is better out.

As a general proposition there is one point that might be emphasized in the discussion, and that is that in comparative estimates there is usually also the question not only of the cost of treatment, but the cost of carrying the sewage to a given point. In most of the estimates that an engineer is called upon to make he has to consider the question of the transportation of the sewage to one or more sites, more or less removed from the center of population. Mr. Eddy has commented upon that in speaking of the area required for the protection of the plant. This suggests, possibly, another element in favor of the activated sludge plant if it can be built close to habitations, thus saving the expense of long intercepting or outfall sewers.

In the studies we are making in the Stock Yards region, if we can save the cost of five or six miles of intercepting sewer, and expensive pumping, and put the plant right in the vicinity of the Stock Yards, we have secured an element in round figures of $500,-000 to $1,000,000, more or less, in favor of the activated sludge plant which would count against the use of tanks and sprinkling filters as a comparative proposition. The same general observation is probably true in many installations on municipal sewage. In small plants, under 50,000 population, the estimates that I have made would indicate that in general, unless there is some element of transportation involved, the tanks and sprinkling filters when capitalized cost less than the activated sludge.

Another point that might be brought out is that in comparison with the practice of twenty years ago or older, the efficiency of sewage treatment is being increased. We are able to do more today with the same money than we could twenty years ago. And I believe we know a deal more today about how to measure the result in terms of efficiency. That is, we can express better what we are really doing in the different processes, and understand their relative values far better than we did twenty years ago. Consequently,

with the same amount of money expended we can make a far better effort. I think that is clearly brought out by the figures Mr. Alvord quoted, comparing chemical precipitation and sprinkling filters.

Mr. Noble: We have a plant at Fort Worth, just starting out on the experimental work. But owing to the vast difference in the sewage at Fort Worth and Chicago we have not a great deal of definite information to give. We are operating slowly, however, but have no figures whatever at the present time.

During Mr. Eddy's paper a question came to my mind that I would like to ask at this time for further discussion; and that is, he figured that he would perhaps make a profit of one dollar per ton on the sludge. In that figure, Mr. Eddy, will you kindly give us your estimate on cost of de-watering and drying, and also the value of the dry sludge?

Mr. Eddy: That figure—$1 per m. g.—was given in the paper more as a typical figure for the sake of comparison than as an actual estimate of the amount which can be obtained from the sale of sludge.

It seems evident at the present time that there will be three steps in the process of preparing for the market the sludge from the aerating tanks, or the tanks in which it is produced. The first I have called sludge concentration, which is accomplished in the sludge sedimentation tanks. Such tanks should provide for a sufficient depth of sludge to cause its compression by its own weight and thus concentrating it from 98 to 99 per cent water, which it would have after an ordinary half hour's period of sedimentation, to from 95 to 97 per cent.

The second step would be the de-watering, which must be done by a press of some type, by a centrifuge, or even by running it onto sand beds in the way in which I assumed in my paper that the sludge would be de-watered.

This second step of de-watering, if done by pressing, I have estimated at $1.70 per million gallons of sewage, for operating charges, and $1.50 for fixed charges.

The third step would be what I have called the drum drying process, taking the sludge at 70 per cent water, or 75 per cent, if necessary—although that is very wet for economical handling in a dryer—and drying it by direct or indirect heat. This is estimated at $1.70 per million gallons of sewage. That would make the total $4.90 per million gallons of sewage treated, which would be about $9.22 per net ton of commercially dry sludge, assuming 1,063 pounds of commercially dry sludge per million gallons of sewage. There is, therefore, a margin of $1.08 per ton between the theoretical value of the fertilizing ingredients and the cost of drying. The value of the sludge is estimated at $10.30 per ton.

I want to say on that point that fundamental data are being obtained under widely different conditions, and, of course, the figures vary accordingly. I have seen the value of commercially

dry sludge estimated as high as $20 a ton, and as low as or lower than the price I have used in the computations. As experience is accumulated it will be found that sludges from different places will differ in composition. Take the sludge produced at the Milwaukee plant, for example,—the sewage is from the Menominee valley intercepting sewer, if I understand correctly, which receives industrial waste from a number of packing houses and tanneries. Such wastes are probably rather high in nitrogen, and sludge from sewage containing them is certain to be richer in nitrogen than the sludge which is obtained from ordinary domestic sewage from a city of 55,000 persons. Again, the sewage from the main drainage works of the city of Boston is from the center of the city, a district which is exceedingly densely populated—portions, I think, as high as 2,500 persons to the acre. This district includes the hotels and restaurants, and consequently is high in grease and high in nitrogen. A sewage from a suburban territory such as that served by the South Metropolitan district, would probably be lower in nitrogen than one from the more congested districts.

Burton J. Ashley, M. W. S. E.: I would like to ask Mr. Eddy with reference to the detailed design of the bottom of the sprinkling filter. I notice it is largely taken up with drains, which, of course, means excellent aeration. The question that arose in my mind when that sketch was on the screen was as to whether there was not some virtue in the cultivation of a mucous or slime bed on the bottom of filters, so that the protozoans might have more chance to operate. My thought on this carries me to Mr. Dibden's experiments with his slate beds, where he laid claim to the excellent destructive and purifying value of the protozoans, earthworms and the like, which were cultivated in the ooze on those slates. I bring this question up to ask whether you thought there was any virtue in a design of bottom to beds that would favor such organic life.

Mr. Eddy: The work which is done by the organisms is intended to be done in the broken stone above the floor, and the work should be completed by the time the water reaches the floor.

Now, regarding the floor, I assume the point that you have in mind is whether that floor is not thicker than necessary, and therefore that it is more expensive and takes up more room than floors of other design. Some floor must be provided. A flat concrete floor may be built but we have felt that the sludge which comes through the trickling filter may accumulate and tend to clog the bed. To obviate that various designs have been made. In some the concrete floor has been laid and half-round tiles placed upon it to provide a passageway for the water to escape rapidly and carry the sludge with it. Another type of floor, like that at Baltimore, is made of grooved concrete covered with flat perforated slabs. Whatever the type of floor it is desirable that it should be easily drained and self-cleansing. The only question which remains,

if I get your point, is as to whether we have not taken up too much depth or thickness with this floor.

Mr. Ashley: No, too much area in drains where the bottom might be flat.

Mr.Eddy: As a matter of fact that floor is ten inches thick. It may be 2 or 3 in. thicker than the concrete floor with the half-round tile which, I think, has been more commonly used than any other type of floor. The difference is comparatively small. The greater thickness may be considered as being obtained at the expense of 2 or 3 in. of stone. The stone in this bed is 10 ft. 3 in. deep.

Mr. Ashley: There is only a small percentage of that floor, according to this design of yours, that lies flat. I think perhaps 66⅔ per cent of that floor area shown on the screen is taken up in inverts.

Mr. Eddy: Well, possibly about that.

Mr. Ashley: Would it not be an advantageous thing to separate those drains by, say a foot or two, leaving a greater space that is flat on which to collect the mucus or the humus where there could be a cultivation or digesting bed for infusorial organisms, earthworms, and the like?

Mr. Eddy: That is the reason we didn't do it. We did not want it to collect there. The sludge which comes down through the stone must go out through the drains. It cannot accumulate on the flat space and ultimately clog the filter. We may be wrong in our theory, but the intention was to avoid flat areas as far as possible.

Mr. Ashley: The question is whether accumulating sludge would build up or not, and whether or not the protozoans would not reduce it, and keep it reduced, those solids which the bacterial action does not reduce.

Mr. Eddy: I have simply my experience from which to answer that question. I have made no special investigation, but from such observations as I have made I think a floor with small flat areas is to be preferred to those of larger ones.

Mr. Ashley: I have uncovered beds where I have seen the action of protozoans which have surprised me, finding that sludge did not collect there. I have had opportunity to uncover and examine many beds and not in a single instance have I ever found clogging in the bottom on account of insufficient frequency of drains in the bottom of beds.

Mr. Eddy: Do you include fish worms in the class of protozoans?

Mr. Ashley: Yes.

Mr. Eddy: But they are not confined to the floor.

Mr. Ashley: Of course not.

Mr. Eddy: They are found up in the stone, although they are more plentiful near the bottom. It is possible that they would keep the sludge stirred up, so that it would be washed out.

Mr. Ashley: Mr. Dibden claims a great deal of efficiency from the destructive action of these earthworms, and diminutive animal life on the surface of his slate beds.

Mr. Eddy: I have seen one of his slate beds. While it did not appear that a high degree of purification was being obtained when I was there, the material in the beds was not particularly offensive, probably because of such action as you describe.

Mr. Ashley: That is what I supposed, in reading Mr. Dibden's writings, and such has been my experience.

Mr. Ashley gives the following citations:

See Sanitary Record, January 7, 1909, page 2.

See Sanitary Record, November 16, 1911, page 465.

See Surveyor, November 1, 1909, page 14.

See Surveyor, May 21, 1909, page 623.

See Surveyor, October 8, 1909, page 412.

See Municipal Journal and Engineering, November 10, 1909, page 712.

E. F. Bahlman: We operated a small tank on the fill and draw plan for about six months under very adverse conditions. Air supply was not dependable and it was impossible to maintain proper activation of the sludge. The liquor treated carried excessive amounts of finely divided straw. We occasionally obtained stable effluent with an air consumption of about 50 cubic feet per gallon. The effluent was of a bright amber color.

We were not fitted to maintain the proper working conditions and do not want to go on record with any data.

W. S. Shields, M. W. S. E.: I have had no experience with the activated sludge process.

I was interested in the comparison. I would like to ask what was done with the sludge that was dried and removed from the sludge drying beds at Fitchburg?

Mr. Eddy: You mean the sludge from the Imhoff tanks?

Mr. Shields: Yes.

Mr. Eddy: That is hauled about the grounds of the plant, and used to furnish humus for the soil and add a little to its fertilizing value. There have been numerous demands from farmers for the privilege of hauling sludge, but they have not been permitted to take any because of the large area about the plant which needs fertilizing and soil. The plant was built on the top of a sand and gravel hill, and soil is needed for the plantings made to beautify the grounds; from appearances there will be no sludge to spare for a number of years.

Mr. Shields: What do you do with it in the winter time?

Mr. Eddy: In the winter sludge is not drawn. There is sufficient surplus capacity in the Imhoff tanks to permit of storing the sludge through the winter.

Chairman DeBerard: How about the life of that industrial track, is that going to last any time?

Mr. Eddy: I would rather deal with facts than prophecies. It

has lasted two years. I don't see any reason why it would not last thirteen more. It is the ordinary industrial track laid on the steel ties which are attached to the rails. I hadn't given the life of that track any particular thought. There is no indication of its disintegration. Of course, the ties are steel, and will rust.

Chairman DeBerard: How about the cement gun work, was that shot up against the expanded metal lath with something for backing?

Mr. Eddy: No; it was shot directly against the steel. The metal is that known as rib-truss. There was no difficulty due to failure of the cement mortar to adhere to the metal.

Chairman DeBerard: Did it build up and close up the openings?

Mr. Eddy: It did, and could be made fairly smooth. As a matter of fact, one of the requirements of the specifications was that it should be left as rough as possible so that the sewage which fell on it or passed through the stone quickly would not find a very easy means of reaching the under-drain; that is, it would have a similar effect to that of so much area of broken stone.

Chairman DeBerard: The reason I asked was because in building some tanks in the vicinity of Chicago it has been the practice to drape the outside or the inside of the tank with canvas and shoot through the expanded metal against the canvas. In that way a surface is built up until the openings were stopped.

Mr. Eddy: These openings were not really openings in the sense that you would have them in punched metal. That is, the steel was cut and pressed in such a way that there were numerous short slits in it which were opened in a plane vertical to the sheet. The mortar, therefore, could not pass directly through the openings but had to pass sideways to escape. There was no trouble in building up the mortar on that steel.

Mr. Neufeld: I would like to ask Mr. Eddy a question regarding the commercial value. He stated ten dollars and some odd cents a ton, and I presume most of that was fertilizer. I noticed recently in one of the publications—I believe it was in Austin,—that there is a concern that is pushing commercial wastes as a fuel. Now, I was trying to get some idea as to what the value of this product would be, whether in certain municipal wastes you would have to increase the value, or whether taking the average municipal waste you could use it as a fuel and whether the value would be higher than as a fertilizer?

Mr. Eddy: We have not made any tests from which I can give you figures on that subject. Judging from such experience as I have had, I should not expect the fuel value of the sludge to be material. If it has value it must be for fertilizing purposes, with the possible exception of the grease in it. My impression is that there is not enough grease in ordinary municipal sewage sludge to make its recovery worth while.

Right here, perhaps you will pardon me if I interject the

results of some work that we have done on tannery wastes, in which the grease is very high. The quantity of air required for oxidation is also very high, about ten cubic feet of air per gallon of wastes. We have found that a very high percentage—I cannot give you the exact figures, but it may be 85 per cent,—of the grease is digested and disappears in the process. This is quite remarkable when it is considered that grease ordinarily is very stable and one of the materials which has caused a great deal of trouble, especially with the intermittent sand filter, due to clogging of the surface of the beds. There was also a very high digestion of all organic matter, but the digestion of the grease was fully as high as that of the remainder of the organic matter.

Mr. Neufeld: I did not have exactly the meaning of fuel in the nature of coal only, although I believe that the concern in Austin was endeavoring to obtain fuel in the nature of coal or coke, judging from the name of their concern. I believe they call themselves the Coke and Coal Company. It is incorporated for the purposes of buying up municipal wastes. Although I doubt whether the value would be there.

Paul Rudnick: I would like to ask Mr. Eddy whether his experience with other kinds of sewage than tannery waste has also shown a definite loss of grease as noticed in the tannery wastes?

Mr. Eddy: I haven't any quantitative figures on that subject. In fact, the experiment on tannery wastes is the only one which has been carried through in all respects quantitatively. Consequently I can hardly answer your question.

Paper mill wastes, of course, contain very little grease. They are susceptible to the activated sludge treatment, although the test which we made was not particularly encouraging.

The woolen mill wastes contain some soaps and some oils, used in the picking process, I believe. But I do not know to what extent that was digested and disposed of.

Mr. Rudnick: I was particularly interested in this phase of the subject, because when you spoke about the loss of grease in tannery wastes, it occurred to me that this grease is probably already oxidized to a very large extent in the hides and that it consists very largely of unsaponifiable matter anyway; so it is hardly surprising that it should be more readily destroyed than fat in other industrial wastes or in municipal wastes. Kitchen refuse, for example, contains mostly hog fat and beef fat, which are comparatively less oxidized or otherwise changed in their nature than the fat of tannery wastes would be. That is the point that I tried to bring out, whether you had any comparisons between fat destruction in treatment of municipal wastes as compared with the special case of tannery wastes.

Chairman DeBerard: Does anybody here have any data at hand on what is being done with strawboard wastes? I think the U. S. Public Health service has been doing a great deal of experimenting down in Ohio on that proposition. I do not have any

figures at hand, but I know that they have tried out practically everything that has been suggested, and are having a hard time to solve the problem. I understand strawboard waste is one of the meanest things to handle.

Mr. Eddy: I do not see why strawboard waste would not be quite comparable with the ordinary papermill waste. This papermill to which I have referred uses as its raw material among other things large quantities of burlap and ropes. They are digested under pressure and heat with alkalies, so that the gums are dissolved out, leaving the cellulose fiber for the manufacture of paper. The materials which are in the wastes, relatively speaking, are very stable. On the other hand, after they are somewhat diluted and the bacteria begin their work,, they can become exceedingly offensive. Now, in treating the wastes artificially it would appear to be necessary to create conditions such that the bacteria can work upon the wastes while passing through the artificial plant, just as they do in the stream. This can be readily done, although it is an expensive proposition.

Mr. Chrisman: I would like to ask if any of the gentlemen present who have worked upon this subject experimentally, have determined anything in regard to the nature of the bacterial flora and the action of those flora upon the sewage directly.

Mr. Eddy: As to the specific organisms in sewage there is comparatively little knowledge. There is, however, abundant evidence of the amount and general character of work which they do. It is evident that the bacteria in the activated sludge tank are performing substantially the same work as those in the trickling filter, the contact bed and the intermittent sand filter. They are oxidizing the organic matter,—the nitrogenous matter and the carbonaceous matter into carbon dioxide.

Mr. Bartow: We have isolated the nitrate and the nitrate-formers from the activated sludge. The work was done by Mr. Russell, and in some cases the nitrate and nitrate formers have been added to the sewage, and together with the protein organisms have given successful results in the destruction of sewage.

Charles B. Burdick, M. W. S. E.: I have had no experience with activated sludge, although I have been an interested bystander for some time. I have been very much interested to hear this comparison of the activated sludge process with one of our well-known sewage processes. The committee is to be congratulated, I think, in going to Boston and securing Mr. Eddy to address us on this subject, for I know of no one more capable of giving us a fair comparison of the merits and costs of this new process and the older processes of purification that every one is watching so carefully.

The public has always shown an eagerness to take up new processes of sewage purification. Just now it is greatly interested in activated sludge. It must not be inferred, even though the activated sludge process should prove to be all that is hoped for,

even although the by-products should prove to be valuable enough to pay for the total cost of purification under some circumstances, even under all these circumstances it does not follow that it is a process that will be universally or even generally adopted for the treatment of municipal sewage.

Almost any one who is familiar with sewerage knows that only a small part of our cities find it necessary to purify their sewage, at all. There is another large group that purify the sewage, but find a partial process, a tankage process of some kind, adequate to all needs of the situation. And it is only those cities that require a rather high degree of sewage purification that will find it necessary to go to the trickling filter or an activated sludge process. As to whether the activated sludge process will form a permanent place in sewage purification is going to depend, as Mr. Eddy has pointed out, largely upon the cost of power, and also upon the ability to produce a by-product that has value. All those who are watching the process are especially interested in the results from the experiments that are being made in the Stock Yards. For it seems that under the circumstances prevailing in the Stock Yards there is the greatest chance to make this new process a success. We have combined here the probability of low power cost, good expert supervision from day to day, and the market already established for a fertilizer providing the process can produce a commercial product at a reasonable cost.

Carl Scholz, M. W. S. E.: I am sorry that the luncheon which you attended today did not come off tomorrow, because this meeting would have enabled me to enlighten the audience which I had at noon today very much better. In the presence of such experts as Messrs. Alvord, Pearse and Bartow I do not feel capable of speaking on the technical side of the drainage problem, but I do feel that I wish to discuss the needs of Chicago with reference to sewage and drainage.

From the observations made during my connection with the Sanitary and Drainage Efficiency Committee of the Chicago Association of Commerce, I have become convinced that the subject of sewage purification is one of vital importance to this city. With its large industrial institutions and the rapidly increasing population surrounding such industrial sections, the treatment of sewage is of even more importance than if the industries were segregated districts and the sewage would not have to be carried through or by residential sections. Perhaps, the most vital problem is that of the Stock Yards, but fortunately the new treatment seems to contain some merits whereby the offal can be converted into economic use. From the activities displayed by the packers, I feel sure that if it is possible to derive some benefits from activated sludge they will do so.

The Drainage Canal, which was supposed to take care of the needs of Chicago for many years to come, is being taxed to its limits now. You all know of the suit pending before the Federal

Court, and the efforts which are being made to limit the flow to the smallest possible amount.

Chicago is also concerned with the sewage problem of its adjoining cities, because the towns lying north and south still empty their raw sewage into the lake. Our activities, therefore, should extend into the territory of our neighbors. Evanston, for instance, has built a treating plant to purify its drinking water, but its sewage still goes into the lake.

It seems pertinent to call the attention of engineers to the great possibilities for fame and financial returns to those who can solve the sewage question, and I think it is the duty of the engineers to inform the laymen who are not familiar with the problem of the great need for action. The sewage contributed by our industries brings our total sewage equivalent to that of a city of four million people, and it is obvious that the problem is one much larger than understood by the average citizen.

CLOSURE.

Mr. Eddy: Mr. Alvord has stated the most vital cause of the unsatisfactory results obtained from many sewage treatment plants —namely, that it is usually impossible to obtain reasonable appropriations and authority for suitable technical supervision. There is no doubt that many of the plants which have failed to perform a really useful service would have rendered such service had they been given intelligent, conscientious, technical supervision. The cost of such supervision is not excessive and no community which is called upon to build a sewage treatment plant, which must be done at great expense if at all, should be permitted to operate the plant without such supervision.

I am glad to know that Dr. Bartow feels that this paper offers some encouragement of the success of the activated sludge process. It would be most unfortunate to have the investigating of so promising a process interrupted by discouraging failures in certain details. It is not to be expected that it can be perfected in all respects in such a brief period as that during which it has been under investigation. Furthermore, the discouraging results thus far obtained relate to difficulties in operation. These difficulties are not insurmountable, although the cost due to them may render the operation expense higher than that of other processes. This, however, is only one element of the problem which is presented in most places, as has been very clearly pointed out by Mr. Pearse, who apparently feels that there is a probability that an activated sludge plant can be successfully operated in the vicinity of the Stock Yards, thus avoiding the expenditure of a large sum of money for a long sewer and pumping station, required to convey the sewage to an isolated site necessary for a trickling filter plant.

The commercial phase of the sludge disposal problem, in which Messrs. Rudnick and Noble are particularly interested, is one about which there may well be serious misgivings. While it is possible

that a profit may be realized from the sale of sludge as a commercial fertilizer, it must be admitted by the most enthusiastic that the margin of profit is much less than that of most commercial enterprises. It must also be recognized that the probability of efficient management and operation of municipal sewage treatment plants is far less than that of commercial enterprises. Taking these two facts into consideration one may well hesitate to advise the expenditure of a large sum of money for the mechanical appliances necessary for converting the liquid sludge into marketable fertilizer until there are more data available to serve as a basis for computation.

As a partial answer to Mr. Rudnick's question, it may be of interest to add that the saponified and unsaponified fats in the tannery wastes are determined separately and that the process of digestion appears to have attacked these two classes of fats about equally.

Mr. Ashley has raised a very interesting question. The presence of the protozoan, the earthworm and other similar worms in great numbers has been reported by numerous observers of trickling filters. To what extent the protozoa perform a useful service in converting putrescible organic matter into humus-like material, is not known. It is obvious, however, that vast quantities of food must be consumed by these organisms and they may perform a very important function in the trickling filter.

Whatever may be their physiological action, it is probable that in their movements they have a physical effect upon the suspended matter in the trickling filter. The periodic unloading of filters following closely upon the increase in temperature of the sewage in the spring, may be due in large measure to such movements.

If either of these facts be true, these protozoa and worms may be responsible for the failure of many trickling filters to become filled near the bottom with suspended matter, where facilities for draining and flushing are not ideal.

The tendency to adopt new processes of sewage treatment, which has been pointed out by Mr. Burdick, seems to be somewhat unfortunate. It implies an inclination to apply a process of sewage treatment regardless of the needs of the case. It is becoming more and more evident that the adoption of a process for the treatment of sewage, should depend upon the local conditions encountered, which will dictate the extent to which the sewage must be treated and the process best adapted to the work in hand. A tendency to adopt a given process to meet all conditions should be discouraged, as such a course is likely to lead to unsatisfactory results.

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings

Meeting No. 952, December 4th, 1916.

The meeting was called to order in the Society rooms at about 8:00 P. M. by President Grant, with about 60 members and guests present.

The Secretary announced that the following had been elected to membership in the Society, under the grades specified:

Jacob L. Jacobs, Chicago.....................................Member
Richard M. Quirk, Chicago................................Student Member
Francis M. Howell, Evanston.............................Student Member
John E. Freeman, Chicago...............................Associate Member
Edwin Hope Verrall, Evanston...........................Student Member
Roy Eugene Berg, Chicago................................Student Member
Samuel E. Sosna, Chicago (Transfer from Student)........Junior Member
Grosvenor W. Stickney, Chicago...............................Member
Frank L. Phipps, Chicago...............................Associate Member

and that the following had made application for admission or transfer:

Thomas Wilson, Chicago.
Vincent Pagliarulo, Chicago.
Byron L. Kelso, Lincoln, Nebraska.
Edward L. Ryerson, Jr., Chicago, transfer from Junior.
R. P. V. Marquardsen, Chicago, transfer from Associate.
Reuben A. Anderson, Chicago.
Irving H. Streicher, Chicago.
Sutton Van Pelt, Chicago.

The President then introduced Mr. George Weston, M. W. S. E., who presented his paper on "Industrial Democracy With Particular Reference to the Relations Between Capital and Labor." Written discussion from Mr. Ira W. Dye, Assoc. W. S. E., was read by the Secretary, and oral discussion followed by Messrs. C. W. Baldridge, G. A. Schilling, R. F. Schuchardt, F. H. Bernhard, A. J. Schafmayer, Murray Blanchard, S. Montgomery, W. R. Roberts, E. N. Lake, E. N. Layfield, Stanley E. Bates, W. W. DeBerard.

The meeting adjourned at 10:40 P. M.

Meeting No. 953, December 11th, 1916.

The meeting was called to order at 7:50 P. M. by Chairman Lacher of the Bridge and Structural Section, with about 65 members and guests present.

In accordance with the rules of the Section, nominations were made for the officers of the Section for the ensuing year, with the following result:

For Chairman—N. M. Stineman.
For Vice-Chairman—O. F. Dalstrom.
For Directors—Prof. M. B. Wells, J. W. Lowell, Jr.

The chairman then introduced Mr. Frank E. Brown, Assoc. W. S. E., who read his paper on "Addition to Union League Club Building," which was illustrated by lantern slides. Discussion followed by Messrs. H. J. Burt, W. W. DeBerard, J. W. Lowell, Jr., J. W. Pearl and G. C. D. Lenth.

The meeting adjourned at 9:30 P. M.

Meeting No. 954, December 18th, 1916.

The meeting was called to order at 8:00 P. M. by Chairman DeBerard of the Hydraulic, Sanitary and Municipal Section, with about 75 members and guests present.

Some humorous lantern slides called attention to the Annual Dinner, to be held on January 10th, after which Chairman DeBerard introduced the speaker of the evening, Mr. Walter W. Marr, Chief Engineer, Illinois State Highway Commission, who read his paper on "Types of Roads for a County Bond Issue," which was illustrated by numerous maps and drawings. Discussion followed by Messrs. Julius G. Gabelman, T. Frank Quilty, W. M. Kinney, M. D. Woolsey, J. W. Lowell, Jr., John D. Riley, B. E. Grant, Stanley E. Bates, V. M. King, J. W. Pearl.

The meeting adjourned at 10:50 P. M.

Note.—The Electrical Section meeting, which was scheduled for December 20th, was postponed until a later date, on account of circumstances which made it impossible for Mr. Freeman to be present.

E. N. Layfield,
Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE TO BE FOUND IN THE LIBRARY OF THE SOCIETY.

Hydro-Electric Power. By Lamar Lyndon. McGraw-Hill Book Co., New York. 1916. Volume I, Hydraulic Development and Equipment, 490 pages, 6 inches by 9 inches. Price, $5.00. Volume II, 360 pages, 6 inches by 9 inches. Price, $3.50.

In the preface to Volume I, the author states that his intention was to produce a work for the guidance of engineers in the practical design of hydro-electric plants, which would have the characteristics of accuracy, clearness and completeness, and that scientific discussion of various hypotheses and theories have been omitted, except in cases where their incorporation in the text was essential to the understanding of the subjects treated.

He states that he has followed current practice in most of the work but that he has been compelled to take issue with a few conclusions which are generally accepted by the engineering profession, as in the theory of uplift pressure under solid dams.

Some repetitions, both of statements and conclusions, are defended on the ground that treatises of this character are seldom read through and that it is both an annoyance and a waste of time to search through every part of a book for data on some single subject. This indicates in a general way the care the author has taken to make his book useful.

The author takes issue with the practice of using steel towers for transmission lines, stating that in his opinion the economical reasons for using wood or concrete poles in preference to steel towers is clear.

The contents of the two volumes are as follows:

Volume I.

Chapter IX. Headworks.
Chapter X. Water Wheels.
Chapter XI. Speed Regulation of Water Works and Abnormal Penstock Pressures.
Mathematical Tables.

Volume II.

Chapter I. Alternating Current Generators.
Chapter II. Transformers.
Chapter III. Switchboards.
Chapter IV. Cranes.
Chapter V. Design and Testing of Power Stations.
Chapter VI. Wires and Cables.
Chapter VII. Insulators.
Chapter VII. Pole and Tower Lines.
Chapter IX. Electric Circuits.
Chapter X. Calculation of Transmission Lines.
Chapter XI. Deflection and Mechanical Stresses in Transmission Lines.
Chapter XII. Line Protection and Accessories.
Chapter XIII. Substations.

Construction of Roads and Pavements. By T. R. Agg, C. E., Professor of Highway Engineering, Iowa State College, Ames, Iowa. Cloth, 6x9 in.; illustrated; 432 pages. Publishers, McGraw-Hill Book Co., Inc., N. Y. Price, $3.00.

With a dozen or so clearly differentiated types of roads and pavements in common use, the matter of writing a book covering their design and construction, which will be reasonably complete, yet not of encyclopedic length, is doubtless a problem. Professor Agg has done an admirable job in covering a very broad subject in comparatively few words, as the book contains only a little over 400 pages of text and is printed in large, readable type.

Essentially it is a college text-book. Space does not permit going very deeply into details of design or construction. However, the information is thoroughly up-to-date and this, together with several useful tables and some well-selected representative specifications, makes the book valuable for reference.

The book is divided into twenty chapters with glossary and index. Each specific type of road and pavement is covered in a separate chapter, beginning with the earth road and ending with sheet asphalt and bituminous concrete. A few other chapters are devoted to such subjects as surveys, street design, selection of type and tests of paving materials.

In the chapters devoted to the various types, two rather novel subheadings are found, namely, "Appliances Used" and "Examples of Good Practice." The first should be of considerable value to the highway engineering college student, impressing upon him, in few words, an idea of construction methods that otherwise might not be so readily appreciated. In other words, tabulated, classified or listed items are always appreciated by the mind educated along technical or engineering lines and attract greater attention than the same information appearing as merely a general description, mixed in indiscriminately with other information.

"Examples of Good Practice" sometimes consist of selected specifications and sometimes of excerpts from addresses or articles which have appeared in one or another of the engineering magazines. While few and brief—not more than two to a chapter on the average—they are of distinct value for reference, combining some of the best ideas of the country's most prominent municipal engineers.

Professor Agg has a few pithy and pertinent words to say about the "chaotic and irrational system of nomenclature—of bituminous materials" and then proceeds to describe the various materials of this class, their origin and characteristics, in a manner refreshingly clear and concise to the highway civil (as distinct from chemical) engineer.

Photographic illustrations are numerous, but, with a few important exceptions, their quality is not nearly up to the standard of the text matter. This is a mechanical detail but of no small importance. A method or detail of construction often may be impressed upon one's mind more forcibly by a well-selected picture than by several pages of text. With pictures which are inferior from the point of view of both subject, detail and printing, this result does not obtain.

Road building is an ever-changing art and scores of improvements in design and construction methods are being introduced each year. Professor Agg's book is up to date, and practices developed as late as the summer of 1916, such as the monolithic brick pavement construction, are covered, though briefly.